Concerning the transmission loss rate, plant service power rate and load factor in each year, the values forecast by IOE were used to estimate the peak power demands.

5.5.6 Adopted Power Demand Forecast

As described in Subsection 5.5.5, the forecasts were made using both the macro method and the sector-separate demand-plus method. Consequently, it was found that there is no large difference between the results forecast by the two methods in the earlier period of about 10 years up to 2010 as can be seen in Figure 5.15. Accordingly, the electric power demands estimated using the macro method were adopted, since these are similar to the actual movements. The adopted energy generation and peak power demands are shown in Figures 5.14 and 5.15.

These adopted electric power demands are generally on the low side as compared with the IOE forecasts, so they are one year behind at around 2005 and one-and-a-half years behind at around 2010 than those forecast by IOE as shown in Figure 5.15.

(1) Whole Country

The peak demand for all Vietnam in 1998 was 3,911 MW. Assuming an annual increase rate of 7.7 %, it is estimated to reach 6,579 MW in 2005, which is roughly 1.7 times greater than the value in 1998. For the period between 2005 and 2010, the peak power demand in 2010 is estimated at 10,148 MW, assuming an annual rate of increase of 9.1 %. Thus, it is forecast that the demand in 2010 will be approximately 2.6 times the value in 1998,.

Concerning the energy generation demand which stood at 21,654 GWh in 1998 as shown in a table of the foregoing Subsection 5.5.4, it is forecast that this will rise to 39,072 GWh in 2005 (at an annual growth rate of 8.8 %) and 61,337 GWh in 2010 (at an annual growth rate of 9.4 %). These demands are 1.8 times and 2.8 times greater than the demand in 1998, respectively.

(2) Demand by Area

Future power demand is forecast for the three areas of North, Central, and South areas. Based on values obtained using the macro method, overall demand is divided to estimate that in each area using the distribution ratio forecast by IOE. The results are listed in the following table:

Results of Regional Power Demand Forecast

Year	Whole Country (MW)	North (MW)	Central (MW)	South (MW)
1999	3,991	1,690	436	1,864
2000	4,285	1,735	485	2,065
2001	4,662	1,846	539	2,277
2002	5,079	1,966	601	2,512
2003	5,533	2,104	666	2,763
2004	6,038	2,259	740	3,039
2005	6,579	2,384	816	3,378
2006	7,178	2,572	897	3,710
2007	7,821	2,782	981	4,058
2008	8,535	3,018	1,075	4,442
2009	9,313	3,272	1,167	4,874
2010	10,148	3,550	1,260	5,338
2011	10,981	3,854	1,356	5,771
2012	11,882	4,184	1,458	6,240
2013	12,858	4,549	1,569	6,740
2014	13,913	4,940	1,693	7,280
2015	15,056	5,382	1,824	7,850

Table 5.1 Number of Staff of EVN Business Units in 1994

Independent Accounting Units	Number of Staff December 1994
1 Power Company No.1	15,285
2 Power Company No.2	5,640
3 Power Company No.3	7,328
4 Power Company Hanoi	2,828
5 Power Company of HCMC	2,972
6 Power Construction Company No.1	2,695
7 Power Construction Company No.2	2,681
8 Power Construction Company No.3	2,982
9 Power Construction Company No.4	2,165
10 Power Investigation and Design Company No.1	2,180
11 Power Investigation and Design Company No.2	1,485
12 Electric Equipment Manufacturer	1,974
13 Power Communication Company	218
14 Financial Company	n.a.
Sub-Total	50,433
Dependent Accounting Units	
15 Pha Lai Power Station	2,329
16 Uong Bi Power Station	1,585
17 Ninh Binh Power Station	1,313
18 Thu Duc Power Station	558
19 Tra Noc Power Station	171
20 Baria Power Station	123
21 Hoa Binh Power Station	909
22 Thac Ba Power Station	280
23 Vinh Son Power Station	138
24 Tri An Power Station	267
25 Thac Mo Power Station	269
26 Da Nhim Power Station	161
27 Transmission Company No.1	799
28 Transmission Company No.2	612
29 Transmission Company No.3	342
30 Transmission Company No.4	1,294
31 National Load Dispatching Center	55
32 Power Communication Center	17
33 Center for Research, Science, Technology, Environment and Computer	39
34 Institute of Energy	186
35 Ham Thuan Dami Management Board	n.a.
36 Phu My Ba Ria Management Board	n.a.
Sub-Total	11,447
Grand Total	**61,880**

Source: "Vietnam- Power Development Project" WB, January 1996

Table 5.2 Summary of Consolidated Profit and Loss Statement of EVN

(For years ended December 31th, 1998 and 1997)

(Unit: VND billion)

Items	1998	1997
Net Sales from Operation	**13,473**	**10,564**
Cost of Sales	(10,836)	(8,128)
Gross Profit	**2,636**	**2,436**
Selling Expense	(205)	(174)
General and Administrative Expense	(578)	(1,076)
Net Operating Profit	**1,854**	**1,185**
Other Profit (Loss)	(218)	(35)
Profit before Tax	**1,636**	**1,151**
Profit Tax (Provision)	(535)	(663)
Profit after Tax	**1,101**	**487**

Source: EVN

Table 5.3 Summary of Consolidated Balance Sheet of EVN

(As at December 31st, 1998 and 1997)

(Unit: VND billion)

tems			Dec.31 1998	Dec.31 1997
Assets				
	Fixed Assets			
		Fixed Assets (net)	18,213	20,067
		Construction in Progress	10,739	7,475
		Total Fixed Assets	**28,952**	**27,542**
	Current Assets			
		Cash	4,085	4,425
		Receivables	5,467	10,583
		Inventories	3,952	3,077
		Others	753	541
		Total Current Assets	**14,257**	**18,626**
Total Assets			**43,209**	**46,168**
Equity and Liabilities				
	Equity			
		Capital and Funds	25,182	24,143
		Undistributed Profit	17	320
		Total Equity	**25,199**	**24,463**
	Long-term Liabilities		**12,825**	**5,340**
	Current Liabilities			
		Payables	4,544	15,572
		Short-term Loan	55	144
		Others	586	649
		Total Current Liabilities	**5,185**	**16,365**
Total Liabilities and Equity			**43,209**	**46,168**

Source: EVN

Table 5.4 Electricity Tariff Schedule of EVN (1/2)

(In effect for whole Vietnam, as of September 1999)

(Unit: VND/kWh)

Items	Effective 1/4/96	Effective 15/5/97 to present
I. Industry and institution		
110 kV and higher		
Regular hours	600	700
Off-peak hours	410	400
Peak hours	880	1150
20 to 110 kV		
Regular hours	620	730
Off-peak hours	450	420
Peak hours	900	1200
6 to 20 kV		
Regular hours	680	770
Off-peak hours	480	450
Peak hours	1000	1250
6 kV and lower		
Regular hours	740	810
Off-peak hours	510	480
Peak hours	1100	1300
II. Agriculture		
6 kV and higher		
Off-peak hours	220	250
Others	550	630
6 kV and lower		
Off-peak hours	240	260
Others	580	660
III. Public lighting	600	?
IV. Water supply		
6 kV and higher	550	720
6 kV and lower	600	760
V. Retail for residential		
Consumption from 0 to 100 kWh	450	500
Consumption from 101 to 150 kWh	600	650
Consumption from 151 to 250 kWh	800	900
Consumption from 251 to 350 kWh	1000	1000
Consumption from 351 kWh and above	1000	1250
VI. Whole sale		
Rural areas		
Residential	360	360
Others	550	650
Non-rural areas		
Residential		
With customers' meter and substation	440	470
With PC's meter and substation	460	490
Others	600	700

Table 5.4 Electricity Tariff Schedule of EVN (2/2)
(In effect for whole Vietnam, as of September 1999)

(Unit: VND/kWh)

Items	Effective 1/4/96	Effective 15/5/97 to present
VII. Business and commercial		
6 kV and higher		
Regular hours	1100	1200
Off-peak hours	750	750
Peak hours	1600	1875
6 kV and lower		
Regular hours	1150	1250
Off-peak hours	770	780
Peak hours	1700	1950
VIII. Foreigners		
Industry		
110 kV and higher		
Regular hours	US cents 7.5/kWh	US cents 7.5/kWh
Off-peak hours	US cents 5.0/kWh	US cents 5.0/kWh
Peak hours	US cents 12.0/kWh	US cents 12.0/kWh
20 to 110 kV		
Regular hours	US cents 8.0/kWh	US cents 8.0/kWh
Off-peak hours	US cents 5.5/kWh	US cents 5.5/kWh
Peak hours	US cents 12.5/kWh	US cents 12.5/kWh
6 to 20 kV		
Regular hours	US cents 8.5/kWh	US cents 8.5/kWh
Off-peak hours	US cents 6.0/kWh	US cents 6.0/kWh
Peak hours	US cents 13.0/kWh	US cents 13.0/kWh
6 kV and lower		
Regular hours	US cents 9.0/kWh	US cents 9.0/kWh
Off-peak hours	US cents 6.5/kWh	US cents 6.5/kWh
Peak hours	US cents 13.5/kWh	US cents 13.5/kWh
Business and commercial		
20 kV and higher		
Regular hours	US cents 10.0/kWh	US cents 10.5/kWh
Off-peak hours	US cents 7.5/kWh	US cents 7.5/kWh
Peak hours	US cents 15.5/kWh	US cents 16.0/kWh
6 to 20 kV		
Regular hours	US cents 11.0/kWh	US cents 11.5/kWh
Off-peak hours	US cents 8.0/kWh	US cents 8.0/kWh
Peak hours	US cents 16.0/kWh	US cents 17.0/kWh
6 kV and lower		
Regular hours	US cents 12.0/kWh	US cents 12.5/kWh
Off-peak hours	US cents 9.0/kWh	US cents 8.5/kWh
Peak hours	US cents 16.5/kWh	US cents 18.0/kWh
Residential		
20 kV and higher	US cents 9.0/kWh	US cents 9.5/kWh
6 to 20 kV	US cents 10.0/kWh	US cents 10.5/kWh
6 kV and lower	US cents 11.0/kWh	US cents 11.5/kWh

Source: EVN

Table 5.5 Historical Trend of Power Consumption (GWh)

Year	Total		Industry		Household		Service and Commerce		Agriculture	
	GWh	AGR(%)	GWh	AGR(%)	GWh	AGR(%)	GWh	AGR(%)	GWh	AGR(%)
1989	5,661		2,621		1,877		698		465	
1990	6,187	109.3	2,847	108.6	2,036	108.5	717	102.7	587	126.1
1991	6,586	106.4	3,080	108.2	2,054	100.8	645	90.0	807	137.6
1992	6,926	105.2	3,193	103.7	2,153	104.8	606	94.0	974	120.6
1993	8,007	115.6	3,645	114.2	3,236	150.3	696	114.9	430	44.1
1994	9,198	114.9	4,059	111.4	3,800	117.4	824	118.4	516	120.0
1995	11,185	121.6	4,614	113.7	4,929	129.7	1,010	122.6	632	122.6
1996	13,374	119.6	5,503	119.3	6,136	124.5	1,092	108.1	643	101.7
1997	15,303	114.4	6,163	112.0	7,221	117.7	1,228	112.5	691	107.5
1998	17,739	115.9	6,813	110.5	8,818	122.1	1,393	113.4	715	103.5
Average Growth Rate 93-98	17.2%		13.3%		22.2%		14.9%		10.7%	

Note: Agricultural datum since 1993 is divided into columns of agricultural and household
AGR = Annual Growth Rate

Source: 1989-1994 JICA Master Plan (1995)
1995-1998 Institute of Energy

Table 5.6 Component Ratio of Consumption

Year	Total		Industry		Household		Service and Commerce		Agriculture	
	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%
1989	5,661	100.0	2,621	46.3	1,877	33.2	698	12.3	465	8.2
1990	6,187	100.0	2,847	46.0	2,036	32.9	717	11.6	587	9.5
1991	6,586	100.0	3,080	46.8	2,054	31.2	645	9.8	807	12.3
1992	6,926	100.0	3,193	46.1	2,153	31.1	606	8.7	974	14.1
1993	8,007	100.0	3,645	45.5	3,236	40.4	696	8.7	430	5.4
1994	9,198	100.0	4,059	44.1	3,800	41.3	824	9.0	516	5.6
1995	11,185	100.0	4,614	41.3	4,929	44.1	1,010	9.0	632	5.7
1996	13,374	100.0	5,503	41.1	6,136	45.9	1,092	8.2	643	4.8
1997	15,303	100.0	6,163	40.3	7,221	47.2	1,228	8.0	691	4.5
1998	17,739	100.0	6,813	38.4	8,818	49.7	1,393	7.9	715	4.0

Source: 1989-1994 JICA Master Plan (1995)
1995-1998 Institute of Energy

Table 5.7 Historical Trend of Generation(GWh)

Year	Total		Hydro		Thermal		Gas Turbine		Diesel	
	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%
1989	7,792	100.0	3,825	49.1	3,462	44.4	68	0.9	437	5.6
1990	8,679	100.0	5,369	61.9	2,841	32.7	58	0.7	411	4.7
1991	9,153	100.0	6,317	69.0	2,425	26.5	101	1.1	310	3.4
1992	9,652	100.0	7,228	74.9	1,887	19.6	218	2.3	319	3.3
1993	10,660	100.0	7,965	74.7	1,776	16.7	601	5.6	318	3.0
1994	12,283	100.0	9,246	75.3	2,124	17.3	632	5.1	281	2.3
1995	14,634	100.0	10,581	72.3	2,929	20.0	1,004	6.9	120	0.8
1996	16,939	100.0	12,008	70.9	3,278	19.4	1,433	8.5	220	1.3
1997	19,139	100.0	11,676	61.0	4,331	22.6	2,918	15.2	214	1.1
1998	20,850	100.0	11,087	53.2	4,807	23.1	4,596	22.0	360	1.7

Source: 1989-1992 JICA Master Plan (1995)
1993-1998 Institute of Energy (excluding buying from IPP)

Table 5.8 Existing Power Plants

(As of end-December,1998)

Type	Name	Number x Capacity (MW)	Installed Capacity (MW)	Share (%)
Hydro			2,854	56.5
	Thac Ba	3x36	108	
	Hoa Binh	8x240	1,920	
	Da Nhim	4x40	160	
	Tri An	4x100	400	
	Thac Mo	2x75	150	
	Vinh Son	2x33	66	
	Small Hydro		50	
Thermal(Coal)			645	12.8
	Ninh Binh	4x25	100	
	Uong Bi	1x50, 1x55	105	
	Pha Lai	4x110	440	
Thermal(Fuel Oil)			198	3.9
	Thu Duc	1x33,2x66	165	
	Can Tho	1x33	33	
Gas Turbine			711	14.1
	Thu Duc GT1-7		128	
	Can Tho GT3/4	2x37.5	75	
	Ba Ria GT1-7		220	
	Phu My	2x144	288	
Diesel			397	7.9
IPP	Hiep Phuoc	2x125	250	4.9
Total			5,055	100.0

Source : EVN

Table 5.9 Results of Generated Electricity

Name	1997		1998	
	GWh	%	GWh	%
Hydro	**11,676.5**	**61.0**	**11,087.8**	**51.2**
Hoa Binh	7,025.7	36.7	6,912.8	31.9
Thac Ba	483.5	2.5	379.0	1.8
Tri An	1,772.7	9.3	1,615.9	7.5
Da Nhim	1,122.0	5.9	1,208.3	5.6
Thac Mo	799.9	4.2	601.8	2.8
Vinh Son	286.2	1.5	210.5	1.0
small Hydro	186.5	1.0	159.5	0.7
Thermal(Coal)	**3,324.6**	**17.4**	**3,479.8**	**16.1**
Pha Lai	2,264.1	11.8	2,386.7	11.0
Uong Bi	540.6	2.8	601.4	2.8
Ninh Binh	519.9	2.7	491.7	2.3
Thermal(Fuel Oil)	**1,007.8**	**5.3**	**1,328.8**	**6.1**
Thu Duc	800.0	4.2	1,081.5	5.0
Can Tho	207.8	1.1	247.3	1.1
Gas Turbine(Gas)	**1,973.2**	**10.3**	**3,437.4**	**15.9**
Ba Ria	1,073.0	5.6	1,456.4	6.7
Phu My2-1	900.2	4.7	1,981.0	9.1
Gas Turbine(Diesel)	**945.9**	**4.9**	**1,159.8**	**5.4**
Thu Duc	267.5	1.4	453.8	2.1
Ba ria	277.3	1.4	179.9	0.8
Thai Binh	0.0	0.0	3.1	0.0
Can Tho	220.0	1.1	427.9	2.0
Phu My2-1	181.1	0.9	95.1	0.4
Diesel	**214.3**	**1.1**	**360.5**	**1.7**
Can Tho	16.6	0.1	43.2	0.2
others	197.7	1.0	317.3	1.5
IPP Hiep Phuoc	**8.6**	**0.0**	**800.1**	**3.7**
Total	**19,150.9**	**100.0**	**21,654.2**	**100.0**

Source : EVN

Table 5.10 Existing Transmission Lines

(As of end-December, 1998)

Existing 500kV Transmission Lines

Section From	Section To	Conductor	Cicuit	Length (km)	Circuit Length (km)
Hoa Binh	Ha Tinh	ACSR330x4	1	343	343
Ha Tinh	Da Nang	ACSR330x4	1	389	389
Da Nang	Pleiku	ACSR330x4	1	259	259
Pleiku	Phu Lam	ACSR330x4	1	496	496
Total		-	-	1,487	1,487

Existing 220kV Transmission Lines

Section From	Section To	Conductor	Cicuit	Length (km)	Circuit Length (km)
Hoa Binh	Ha Dong	ACK500	2	55.3	110.6
Hoa Binh	Chem	ACK500	1	63.4	63.4
Hoa Binh	Thanh Hoa	ACK300	1	205.0	205.0
Hoa Binh	Hoa Lu	ACK300x2	1	161.0	161.0
Hoa Lu	Nam Dinh	ACK400	1	33.0	33.0
Hao Lu	Ha Dong	ACk300	1	99.2	99.2
Ha Dong	Chem	ACK500	1	17.0	17.0
Ha Dong	Pha Lai	ACK400	1	80.0	80.0
Ha Dong	Mai Dong	ACK400	1	32.0	32.0
Mai Dong	Pha Lai	ACK400	1	72.0	72.0
Pha Lai	Dong Hoa	ACK400	1	54.0	54.0
Thanh Hoa	Vinh	ACK300	1	161.0	161.0
Vinh	Dong Hoi	ACK300	1	200.0	200.0
Pleiku	Qui Nhon	AC300	1	140.0	140.0
Pleiku	Krongbuk	AC500	1	141.0	141.0
Phu Lam	Cay Lai	AC400	1	75.0	75.0
Phu Lam	Cay Lai	ACSR411	1	62.0	62.0
Cay Lai	Tra Noc	ACSR411	1	84.4	84.4
Tra Noc	Rach Gia	AC300	1	75.0	75.0
Phu Lam	Hoc Mon	AC400	1	16.3	16.3
Phu Lam	Hoc Mon	ACSR411	1	16.3	16.3
Hoc Mon	Tri An	ACK400	2	52.3	104.6
Hoc Mon	Sai Gon	ACSR411	1	14.6	14.6
Sai Gon	Long Binh	ACSR795	1	18.4	18.4
Long Binh	Tri An	AC300	1	22.9	22.9
Long Binh	Phu My junction	ACSR795	2	43.4	86.8
Phu My junction	Ba Ria	ACSR796	2	20.5	41.0
Phu My junction	Phu My	AC400	2	4.2	8.4
Long Binh	Bao Loc	ACSR795	1	130.0	130.0
Bao Loc	Da Nhim	ACSR795	1	110.0	110.0
Total		-	-	-	2,435

Source : NLDC

Table 5.11 Existing Substations

(As of end-December, 1998)

Existing 500kV Substations

Name	Voltage (kV)	Number x Capacity (MVA)	Capacity (MVA)
Hoa Binh	500/220	2 x 450	900
Da Nang	500/220	1 x 450	450
Pleiku	500/220	1 x 450	450
Phu Lam	500/220	2 x 450	900
Total	-	-	2,700

Existing 220kV Substations

Name	Voltage (kV)	Number x Capacity (MVA)	Capacity (MVA)
Hoa Binh	220/110	2 x 63	126
Ha Dong	220/110	2 x 250	500
Chem	220/110	2 x 125	250
Mai Dong	220/110	2 x 125	250
Dong Hoa	220/110	2 x 125	250
Hoa Lu	220/110	1 x 125	125
Thanh Hoa	220/110	1 x 125	125
Vinh	220/110	1 x 125	125
Nam Dinh	220/110	1 x 125	125
Dong Hoi	220/110	2 x 63	126
Da Nang	220/110	1 x 125	125
Pleiku	220/110	1 x 125	125
Quy Nhon	220/110	1 x 125	125
Krongbuk	220/110	1 x 63	63
Da Nhim	220/110	2 x 63	126
Bao Loc	220/35	1 x 25	25
Tri An	220/110	1 x 63	63
Long Binh	220/110	1 x 125, 1 x 250	375
Sai Gon	220/66	2 x 78, 1 x 125	281
Hoc Mon	220/110	1 x 125, 1 x 250	375
Phu Lam	220/110	2 x 125	250
Cai Lay	220/110	1 x 125	125
Tra Noc	220/110	1 x 125, 1 x 100	225
Rach Gia	220/110	1 x 125	125
Total	-	-	4,410

Source : NLDC

Table 5.12 Power Demand Forecast by EVN

Year	Whole Country		Peak Load by Region					
	Generation (GWh)	Peak Load (MW)	North		Central		South	
			MW	Ratio	MW	Ratio	MW	Ratio
1999	22,836	4,059	1,739	0.424	449	0.109	1,918	0.467
2000	25,277	4,477	1,820	0.405	509	0.113	2,167	0.482
2001	28,065	4,942	1,959	0.396	572	0.116	2,416	0.488
2002	31,191	5,470	2,103	0.387	643	0.118	2,688	0.495
2003	34,725	6,069	2,282	0.380	722	0.120	2,997	0.499
2004	38,605	6,731	2,476	0.374	811	0.123	3,331	0.503
2005	42,886	7,447	2,660	0.362	910	0.124	3,769	0.514
2006	47,010	8,132	2,862	0.358	998	0.125	4,129	0.517
2007	51,598	8,882	3,106	0.356	1,095	0.125	4,530	0.519
2008	56,699	9,721	3,379	0.354	1,204	0.126	4,974	0.520
2009	62,339	10,646	3,675	0.351	1,311	0.125	5,475	0.523
2010	68,627	11,653	4,011	0.350	1,423	0.124	6,031	0.526
2011	74,838	12,675	4,375	0.351	1,539	0.123	6,551	0.526
2012	81,611	13,811	4,771	0.352	1,662	0.123	7,115	0.525
2013	88,937	15,038	5,206	0.354	1,796	0.122	7,714	0.524
2014	96,773	16,350	5,667	0.355	1,942	0.122	8,352	0.523
2015	105,557	17,847	6,204	0.357	2,102	0.121	9,048	0.521

Source : Institute of Energy

Table 5.13 Power Demand Forecast (Industry)

Year	GDP		Sales(GWh)		
	GDP(bil.VND)	Growth Rate	Results	Growth Rate	Forecast
1995	12,954	0.11690	4,614	0.13873	Elasticity Coefficient =1.186
1996	14,468		5,503		
1997	16,160		6,163		
1998	18,049		6,813		
1999		0.09336			7,567
2000		0.09340			8,406
2001		0.09339			9,337
2002		0.08765			10,307
2003		0.08765			11,379
2004		0.08765			12,562
2005		0.08765			13,867
2006		0.10101			15,529
2007		0.10101			17,389
2008		0.10101			19,472
2009		0.10101			21,805
2010		0.10101			24,417
2011		0.09039			27,034
2012		0.09039			29,933
2013		0.09039			33,141
2014		0.09039			36,694
2015		0.09039			40,628

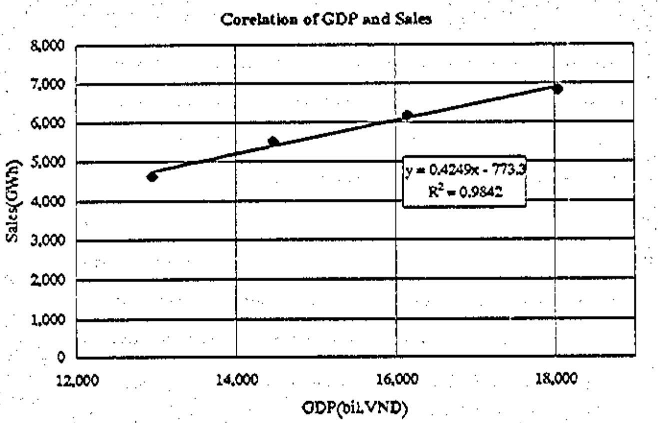

Table 5.14 Power Demand Forecast (Commercial)

Year	GDP		Sales(GWh)		
	GDP(bil.VND)	Growth Rate	Results	Growth Rate	Forecast
1993	15,673	0.12489	696	0.14886	Elasticity Coefficient =1.192
1994	17,693		824		
1995	19,975		1,010		
1996	22,416		1,092		
1997	25,155		1,228		
1998	28,229		1,393		
1999		0.03780			1,456
2000		0.05752			1,556
2001		0.08179			1,707
2002		0.07811			1,866
2003		0.07811			2,040
2004		0.07811			2,230
2005		0.07811			2,438
2006		0.06749			2,634
2007		0.06749			2,845
2008		0.06749			3,074
2009		0.06749			3,322
2010		0.06749			3,589
2011		0.05578			3,828
2012		0.05578			4,082
2013		0.05578			4,353
2014		0.05578			4,643
2015		0.05578			4,952

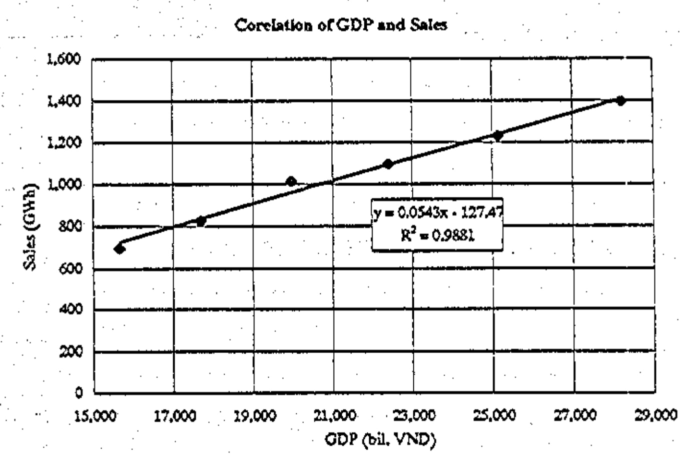

Table 5.15 Power Demand Forecast (Agiculture)

Year	GDP		Sales(GWh)		
	GDP(bil.VND)	Growth Rate	Results	Growth Rate	Forecast
1995	12,051	0.04088	632	0.04200	Elasticity Coefficient =1.027
1996	12,544		643		
1997	13,056		691		
1998	13,590		715		
1999		0.01766			728
2000		0.01764			741
2001		0.01762			755
2002		0.02866			777
2003		0.02866			800
2004		0.02866			823
2005		0.02866			847
2006		0.01601			861
2007		0.01601			876
2008		0.01601			890
2009		0.01601			905
2010		0.01601			919
2011		0.01056			929
2012		0.01056			939
2013		0.01056			950
2014		0.01056			960
2015		0.01056			970

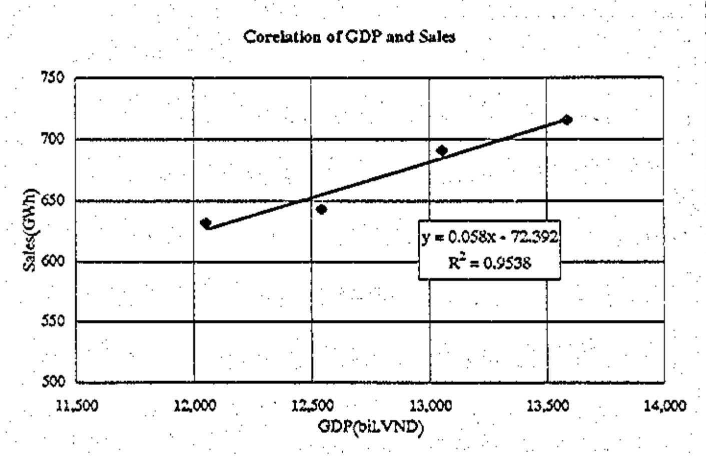

Table 5.16 Power Demand Forecast (Household)

Year	Population	Sales(GWh)	
		Results	Forecast
1994	72,510	3,800	
1995	73,962	4,929	
1996	75,355	6,136	
1997	76,714	7,221	
1998	78,059	8,818	
1999	79,506		9,901
2000	80,937		11,173
2001	82,394		12,469
2002	83,548		13,494
2003	84,717		14,535
2004	85,903		15,589
2005	87,106		16,659
2006	88,238		17,666
2007	89,385		18,686
2008	90,547		19,719
2009	91,725		20,766
2010	92,917		21,826
2011	94,032		22,817
2012	95,160		23,821
2013	96,302		24,836
2014	97,458		25,864
2015	98,627		26,904

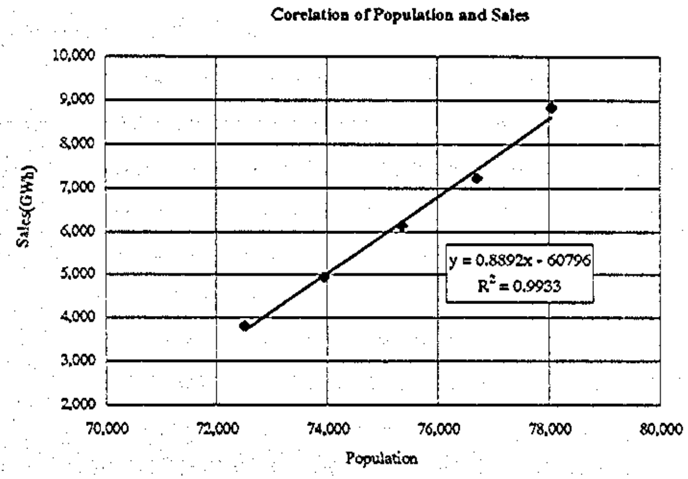

Table 5.17 Power Source Development Plan (1999-2020) by EVN

Year	Name	Capacity (MW)	Total Capacity (MW)
1999	Phu My 2-1	2x140	
	Ba Ria 306-1	56	
	Can Tho 3,4	1x37.5	
	Yaly 1	1x180	
	Song Hinh 1	35	588.5
2000	Wartsila (IPP)	120	
	Yaly 2,3,4	3x180	
	Phu My 1	3x240	
	Ham Thuan 1	1x150	
	Da Mi 1	1x88.5	
	Song Hinh 2	35	1653.5
2001	Pha Lai 1,2	2x300	
	Phu My 1	370	
	Phu My 2-1	143	
	Na Duong (Thermal)	2x50	
	Ham Thuan 2	1x150	
	Da Mi 2	1x88.5	1451.5
2002	Ba Ria 306-2	56	
	Cao Ngan (Thermal)	2x50	
	Phu My 2-1	140	
	Phu My 2-2	720	1016
2003	Phu My 3	720	
	Can Don (Hydro South)	72	792
2004	O Mon 1,2	2x300	
	Uong Bi	300	900
2005	Gas Thermal Western (or Soc Trang)	1x360	
	Rao Quan (Hydro Central)	80	
	Dai Ninh	2x150	
	Geothermal	50	790
2006	Dai Thi (Hydro North)	300	
	Soc Trang (or Gas Thermal Western)	475	
	Geothermal	50	825
2007	Se San3 (Hydro Central)	260	
	Thai Binh (Gas Thermal North)	300	
	Dong Nai 3	1x250	
	Gas Thermal Western #2	1x360	1170
2008	Hai Phong #1 (Thermal)	1x300	
	Gas Thermal Western #3	1x360	
	Import from Laos	300	
	Dong Nai 4	1x286	1246
2009	Hai Phong #2 (Thermal)	1x300	
	Import from Laos	300	
	Gas Thermal Western #4	1x360	
	Quang Ninh #1 (Coal Thermal North)	1x300	
	Geothermal	50	1310
2010	Import from Laos	400	
	Quang Ninh #2(Coal Thermal North)	1x300	
	Qua Dat (Hydro North)	120	
	Gas Thermal Western #5	1x360	
	Geothermal	50	1230
2011	Gas Thermal Western #6	1x360	
	Thuong Kon Tum (Hydro Central)	260	
	Import from Laos	300	
	An Khe (Hydro Central)	155	1075
2012	Son La 1,2	2x300	
	Song Tranh2 (Hydro Central)	200	
	Import from Laos	300	
	Nhon Trach 1(Gas Thermal)	1x300	1400
2013	Son La 3,4	2x300	
	Pley Kron (Hydro Central)	120	
	Import from Laos	400	
	Nhon Trach 2(Gas Thermal)	1x300	1420
2014	Son La 5,6	2x300	
	Se San4 (Hydro Central)	340	
	Nhon Trach 3,4(Gas Thermal)	2x300	
	Ha Song Ba	200	1740
2015	Son La 7,8,9	3x300	
	Buon Kuop (Hydro Central)	277	
	Gas Thermal South	3x300	2077
2016	Gas Thermal South	2x300	
	Son La 10,11,12	3x300	
	A Vuong (Hydro)	145	1645
2017	Gas Thermal South	3x300	
	Quang Ninh #3(Coal Thermal North)	1x300	
	Dong Nai 6 (Hydro South)	180	1380
2018	Coal Thermal	2x500	
	Bac Me (Hydro North)	290	
	Import	500	
	Song Con 2 (Hydro Central)	200	1990
2019	Nuclear	600	
	Dong Nai 8 (Hydro South)	195	
	Import	500	
	Coal Thermal	2x500	2295
2020	Nuclear 2	600	
	Import	2x500	
	Coal Thermal	500	
	Serepok (Hydro)	190	
	Huoi Quang (Hydro North)	500	2790

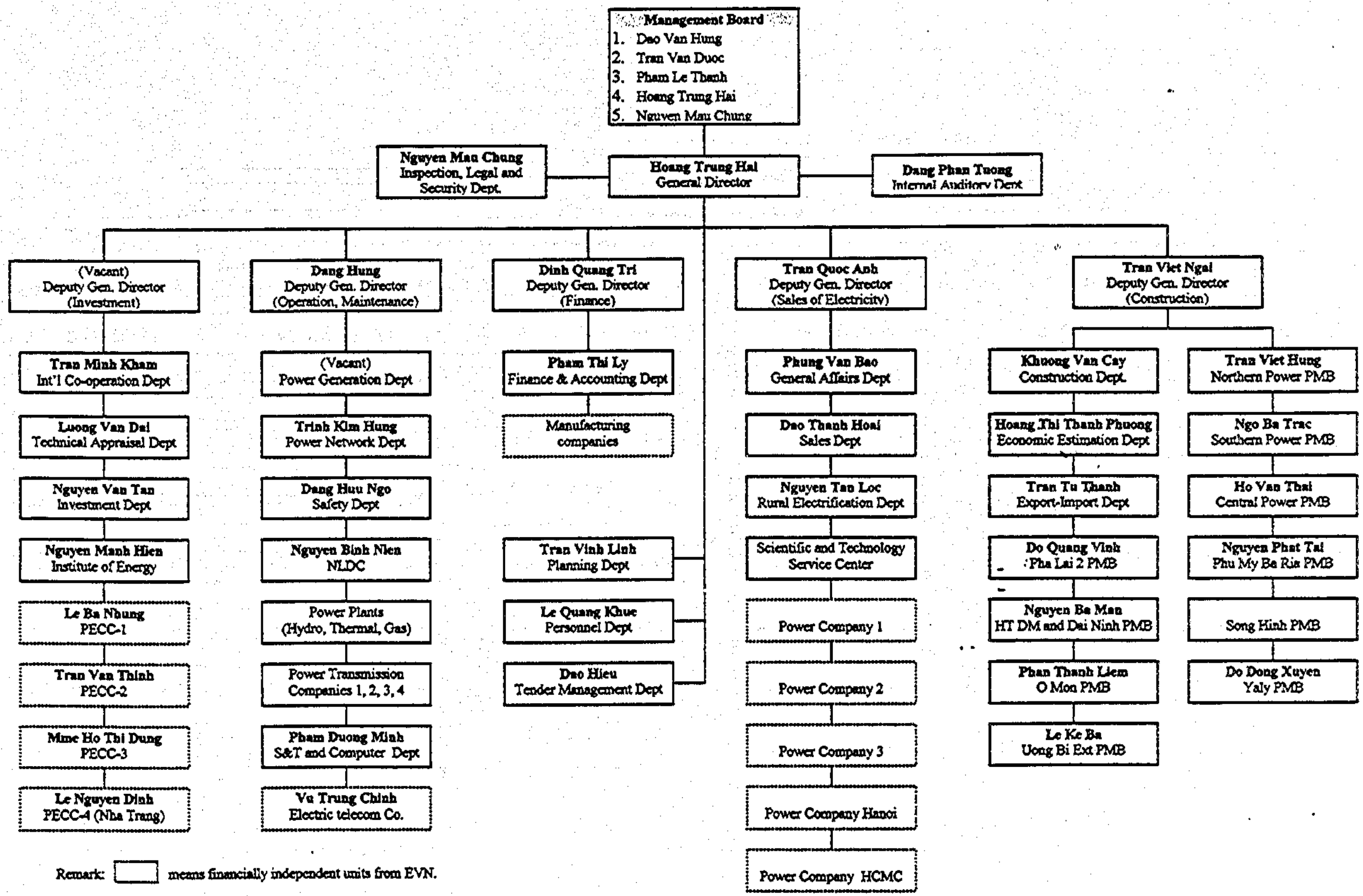

Figure 5.1 Organizational Structure of Electricity of Vietnam as of July 1999

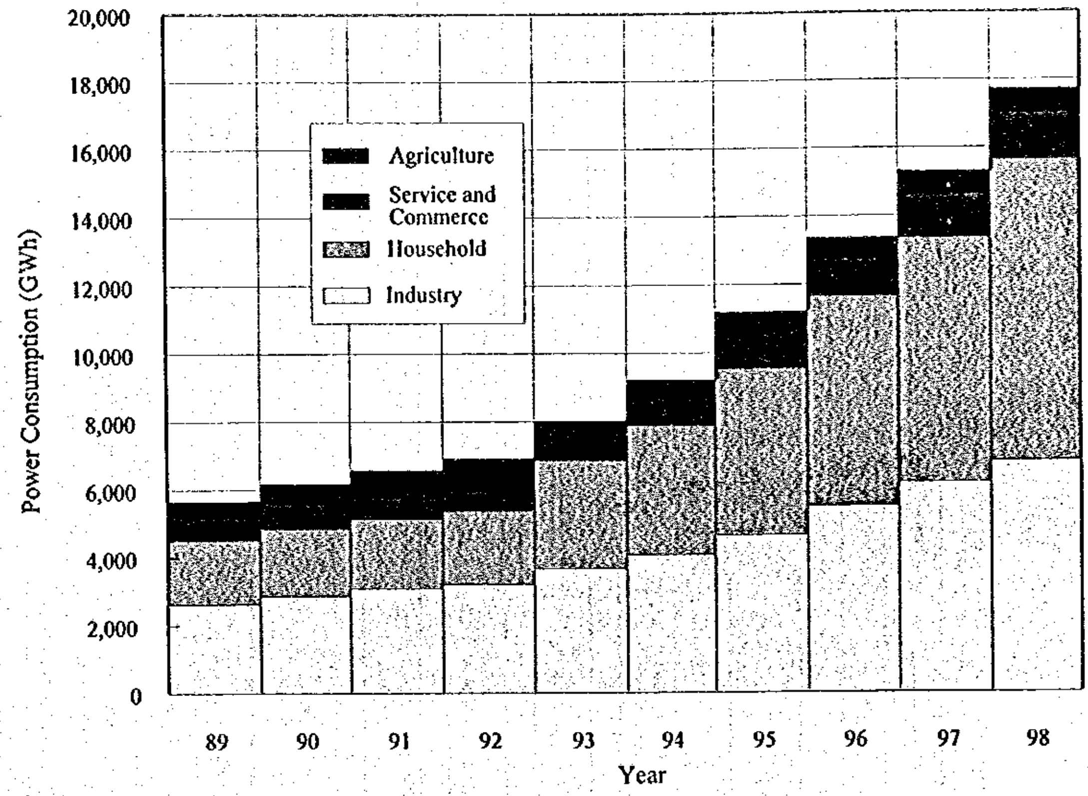

Figure 5.2 Historical Trend of Power Consumption

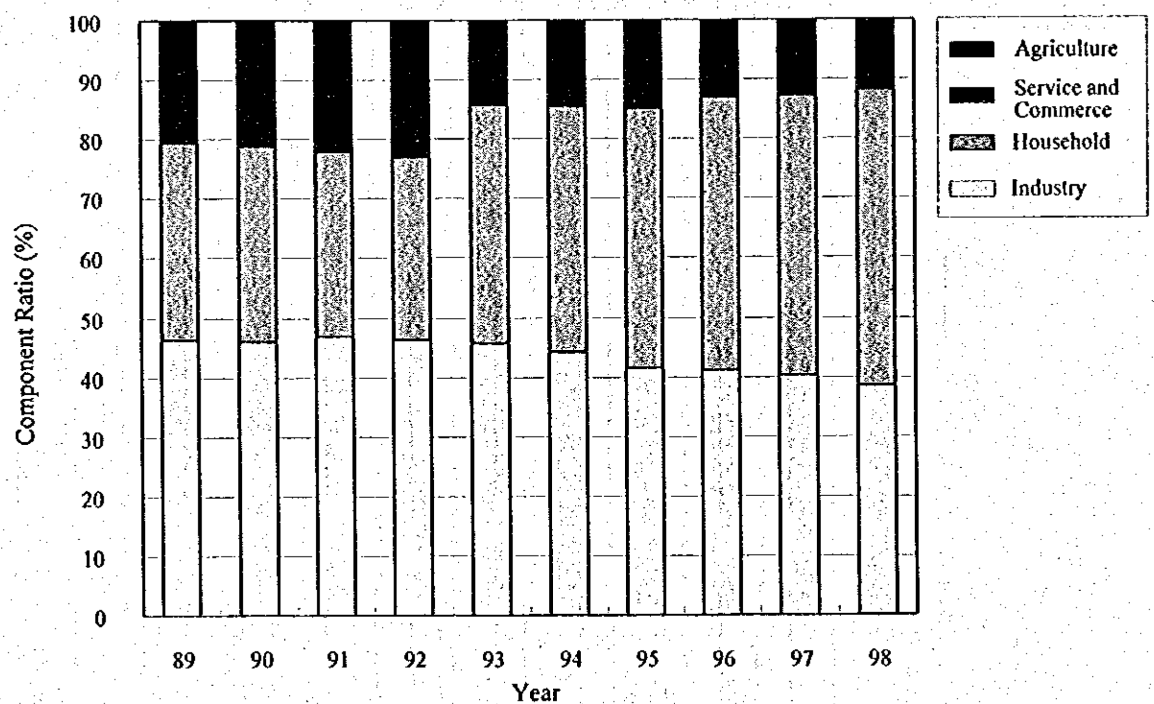

Figure 5.3 Component Ratio of Power Consumption

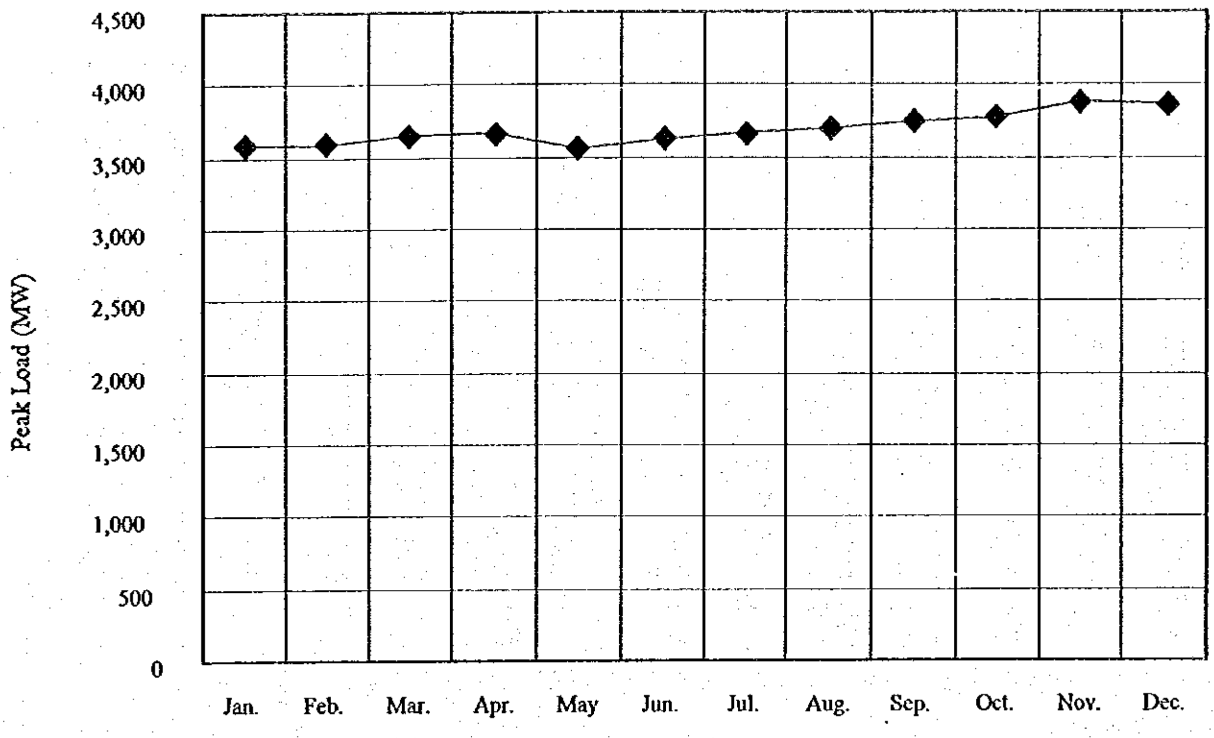

Figure 5.4 Monthly Peak Load of 1998

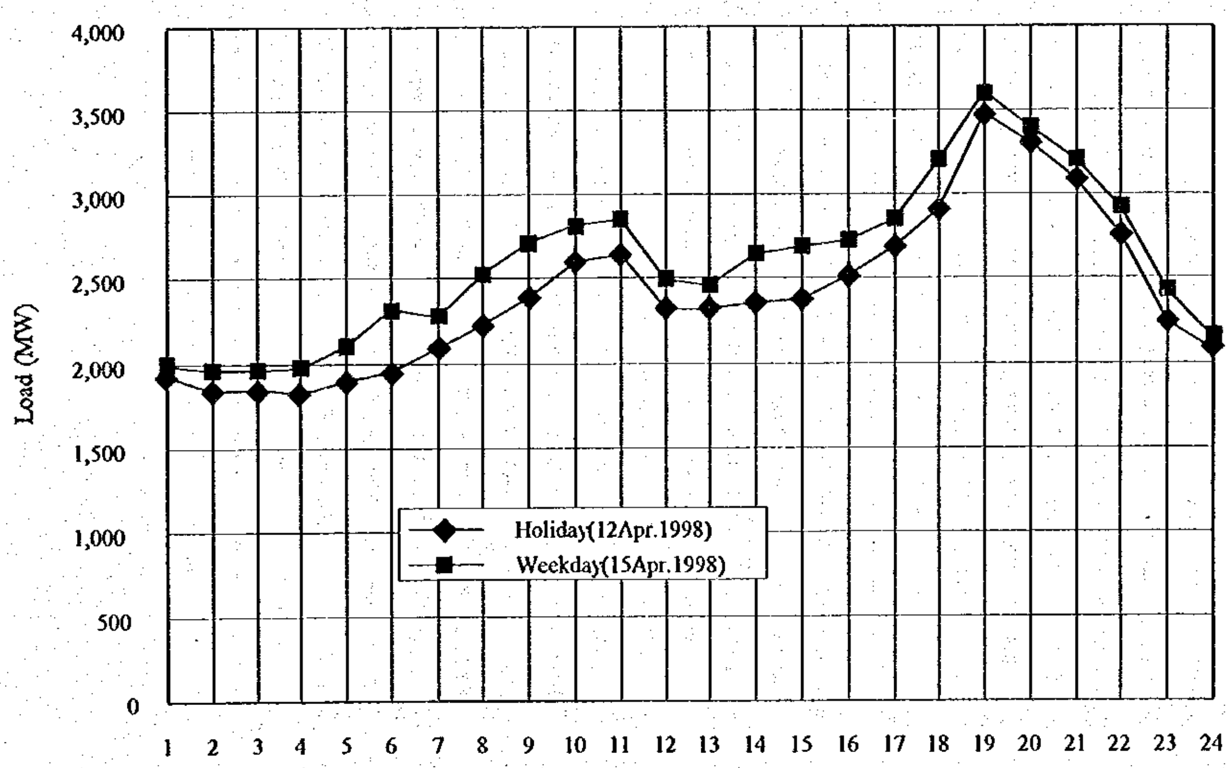

Figure 5.5 Daily Load Curve

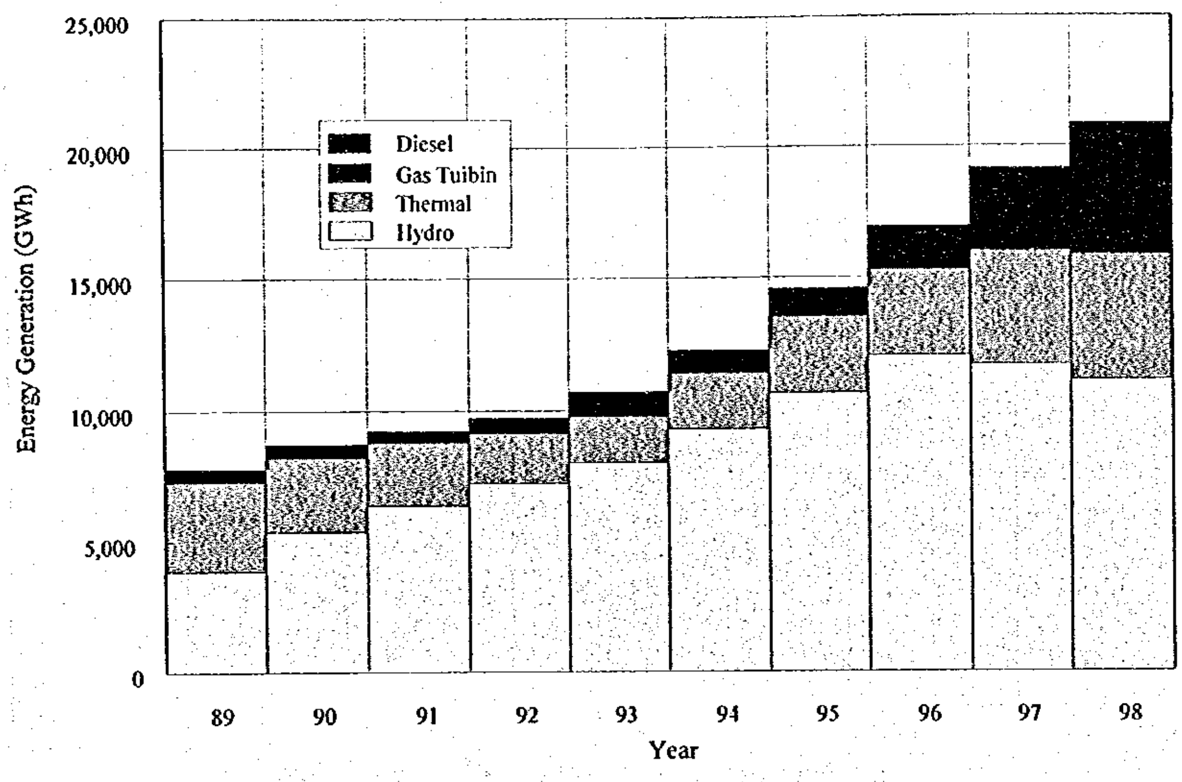

Figure 5.6 Historical Trend of Generation

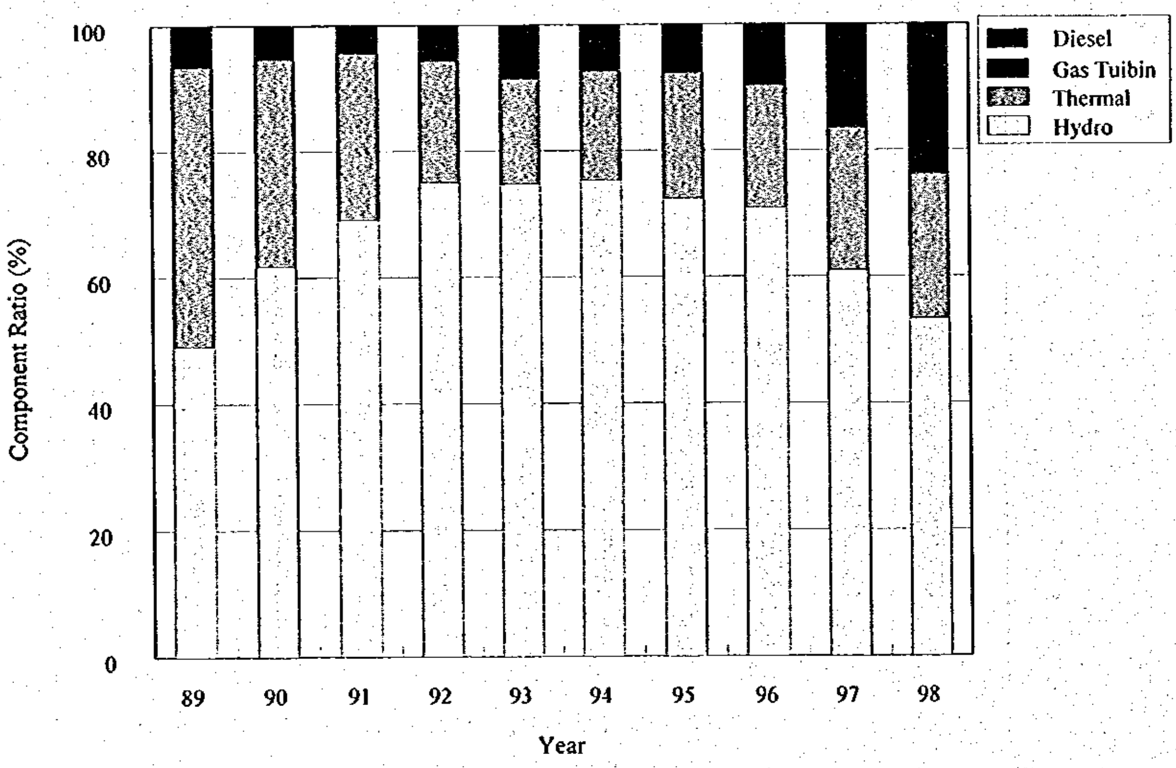

Figure 5.7 Component Ratio of Generation

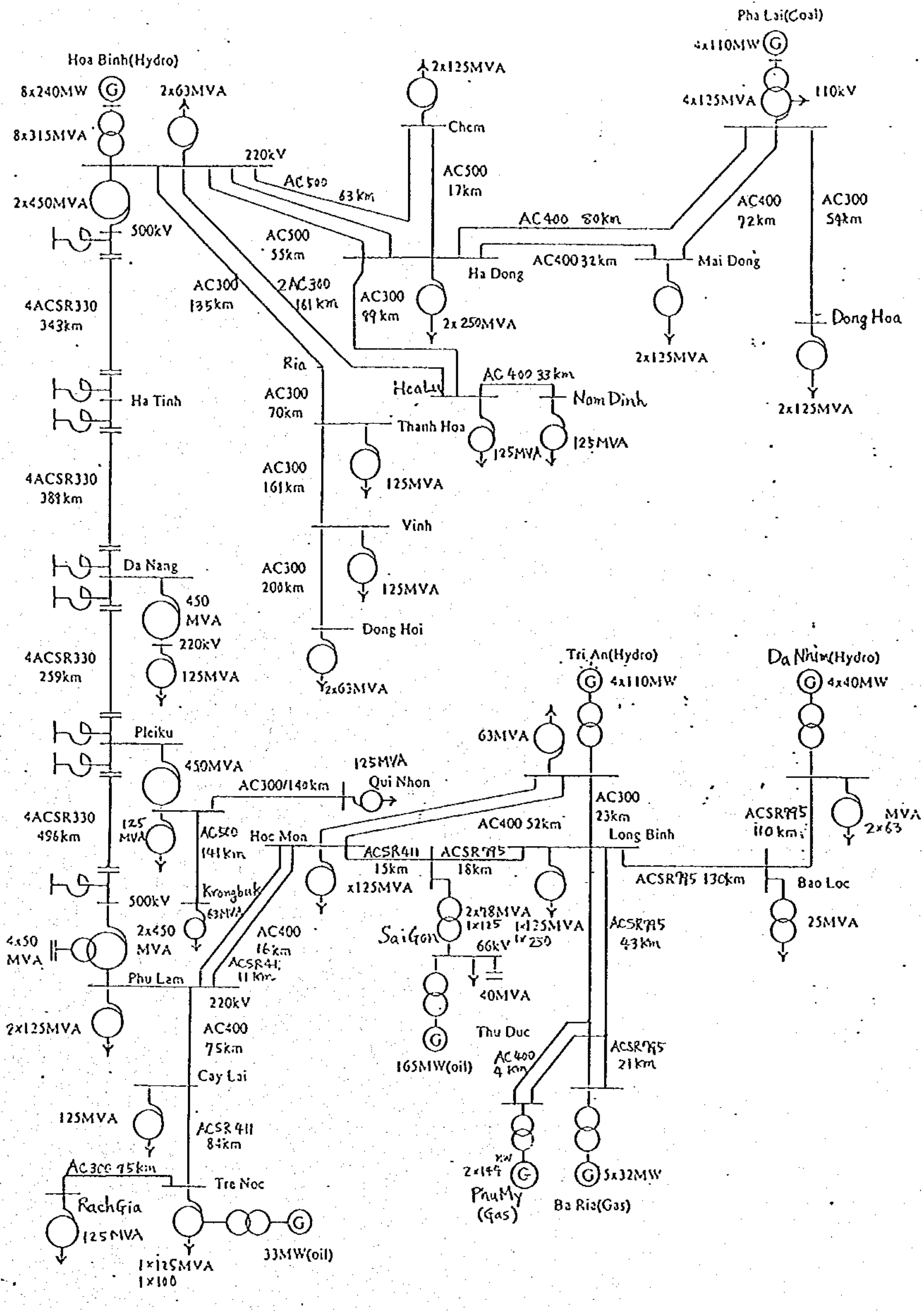

Figure 5.8 Existing 500kV, 220kV Power System Diagram
(As of December, 1998)

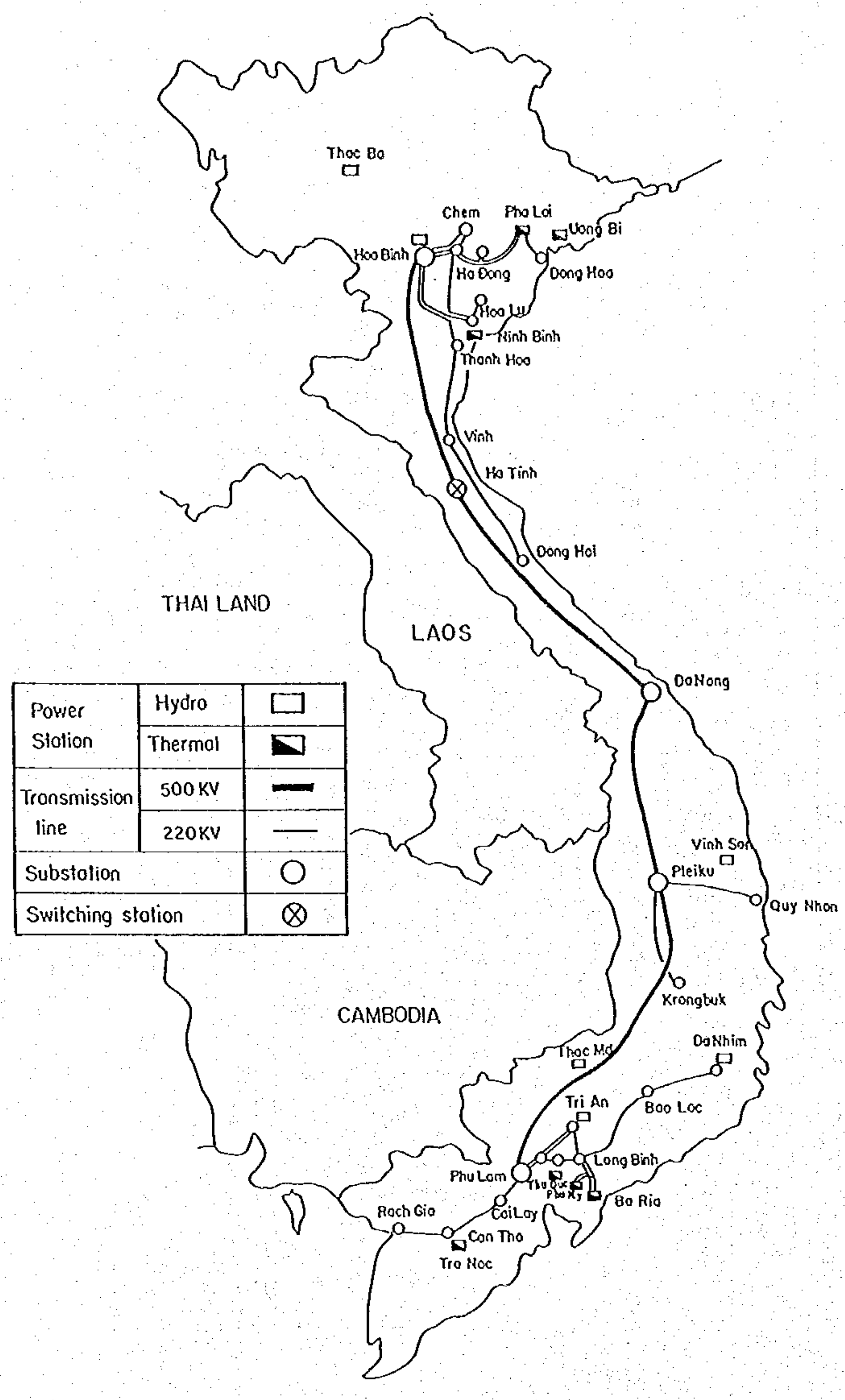

Figure 5.9 Location Map of Existing 500kV, 220kV Power System
(As of December, 1998)

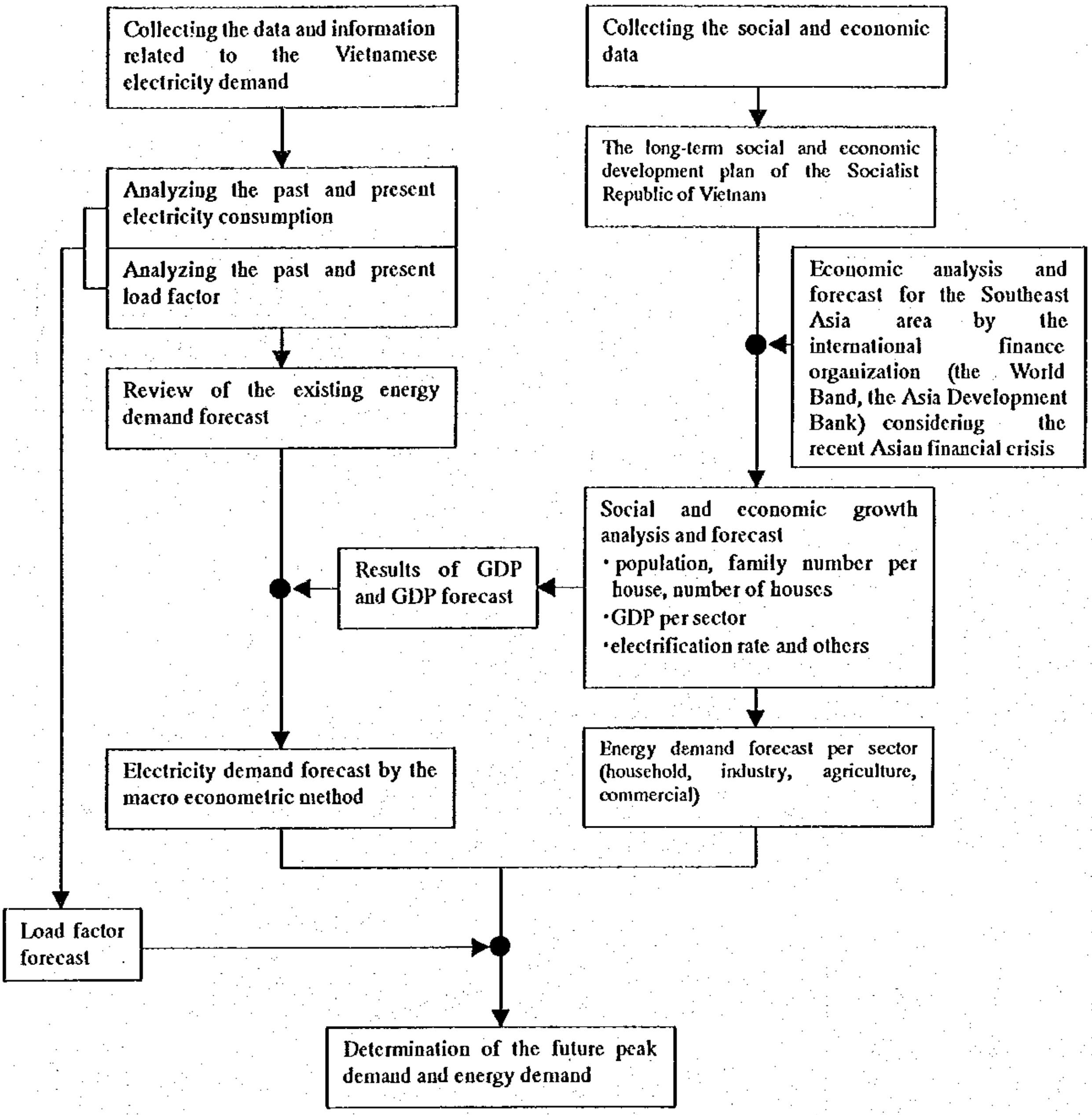

Figure 5.10 Work Flow of Power Demand Forecast

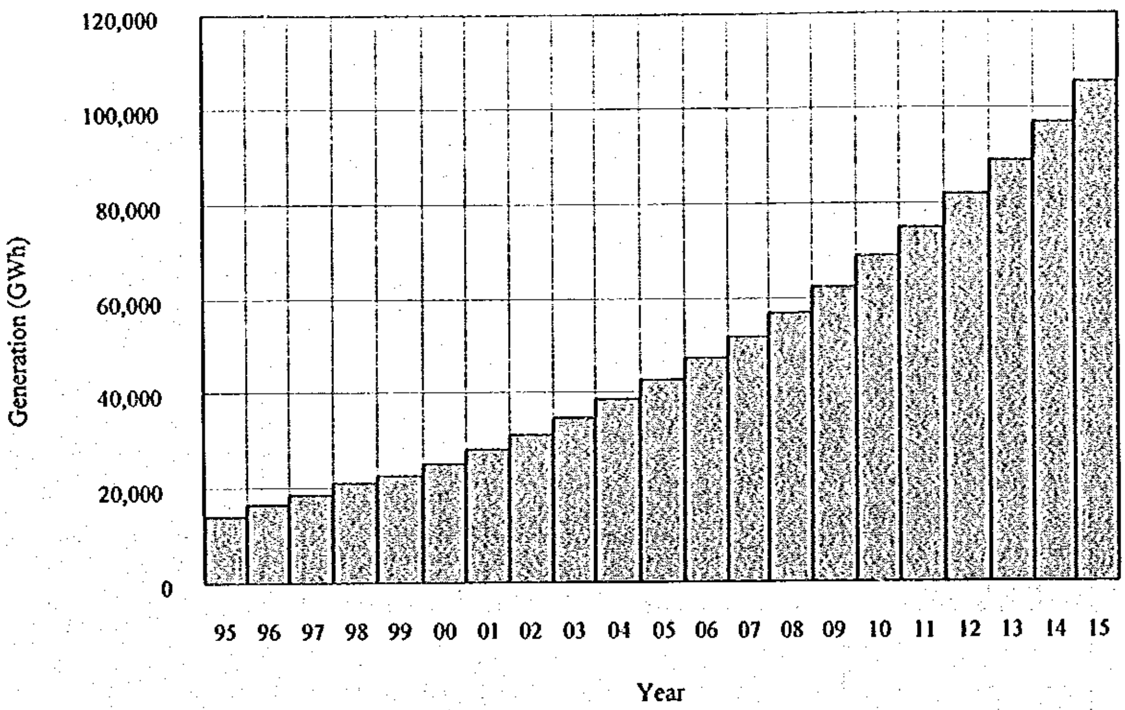

Figure 5.11 Generation Forecast by EVN

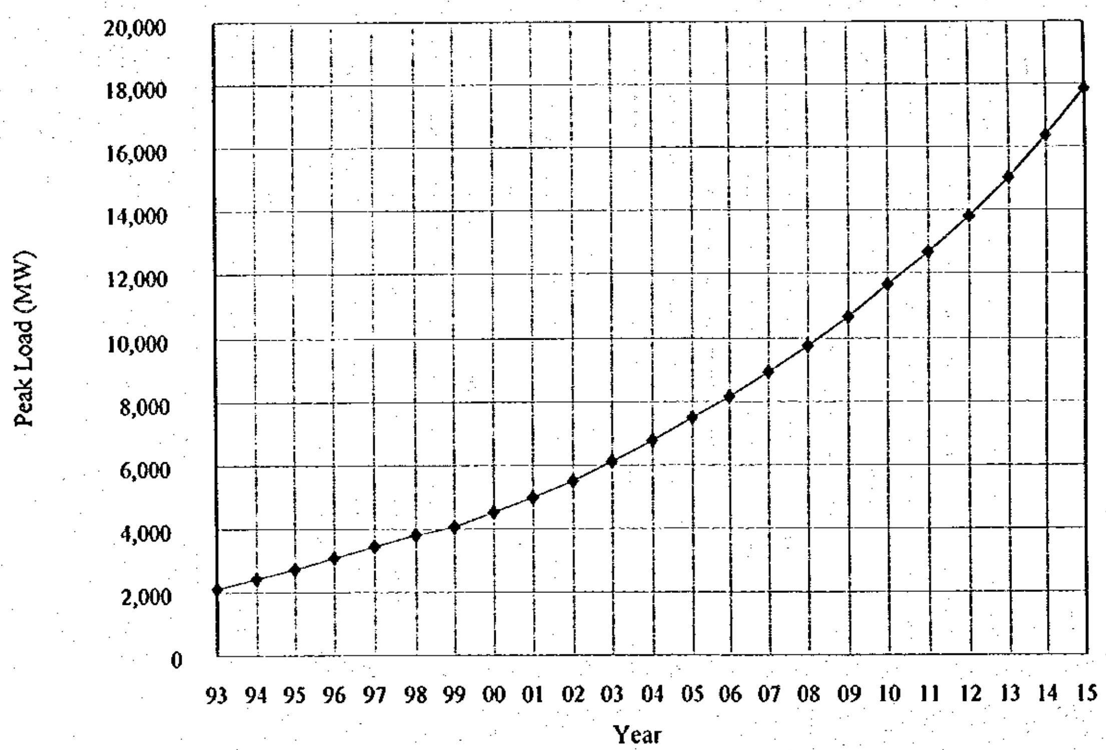

Figure 5.12 Peak Load Forecast by EVN

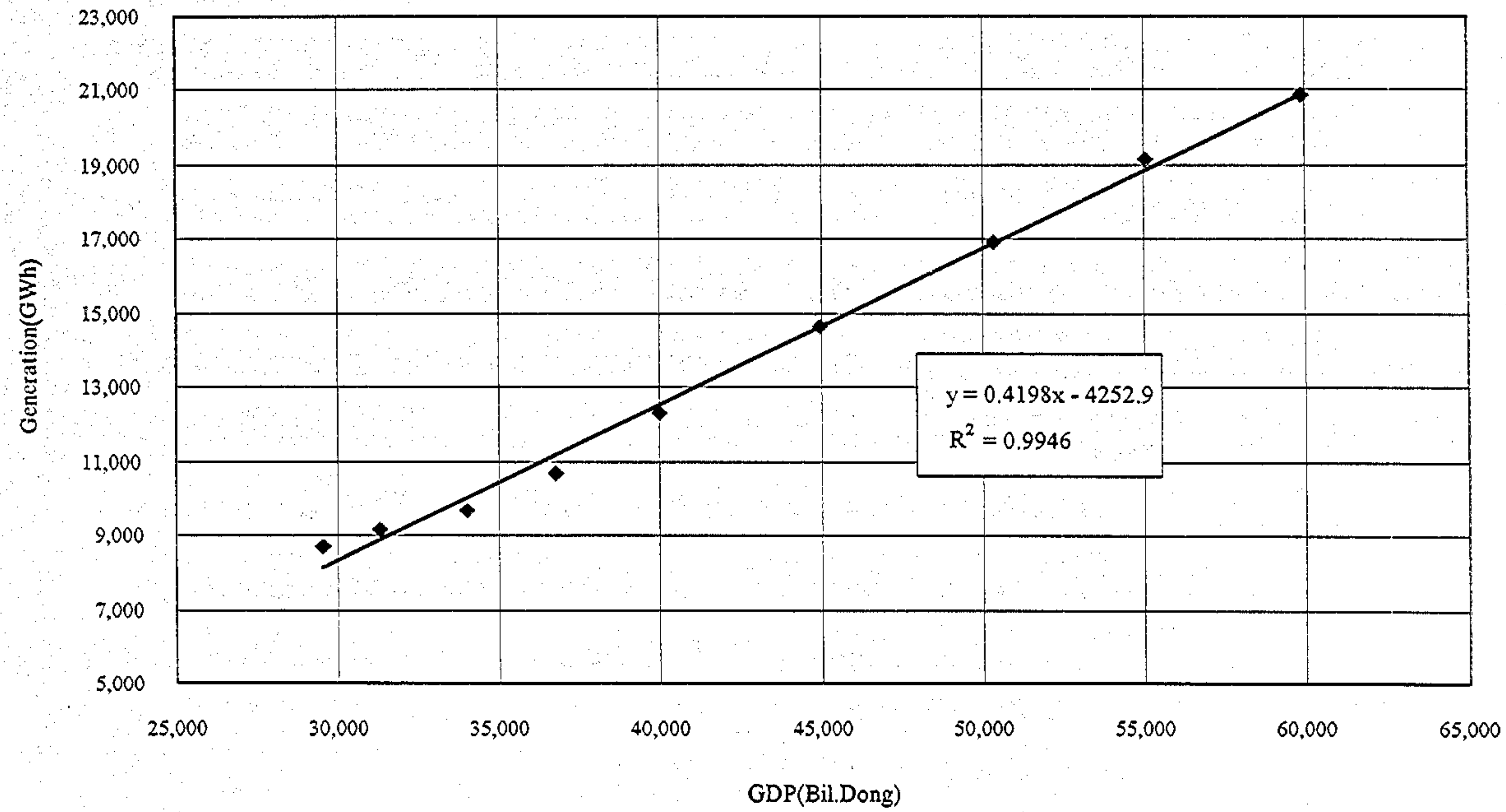

Figure 5.13 Correlation between GDP and Generation

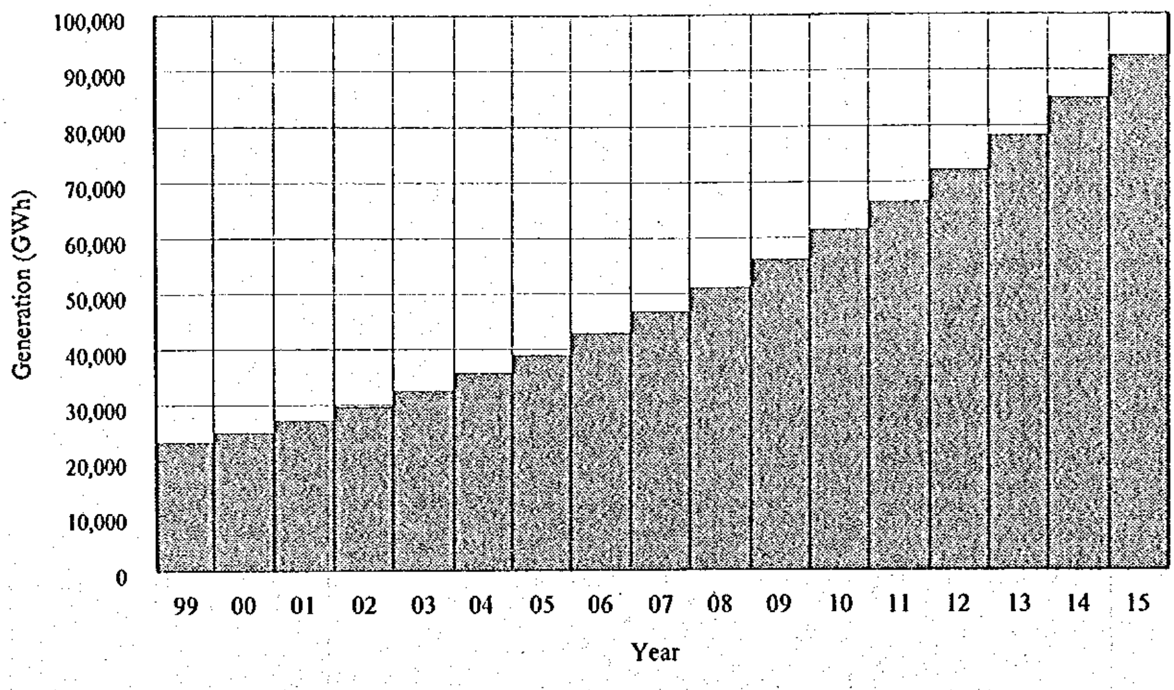

Figure 5.14 Generation Forecast by the JICA Study Team

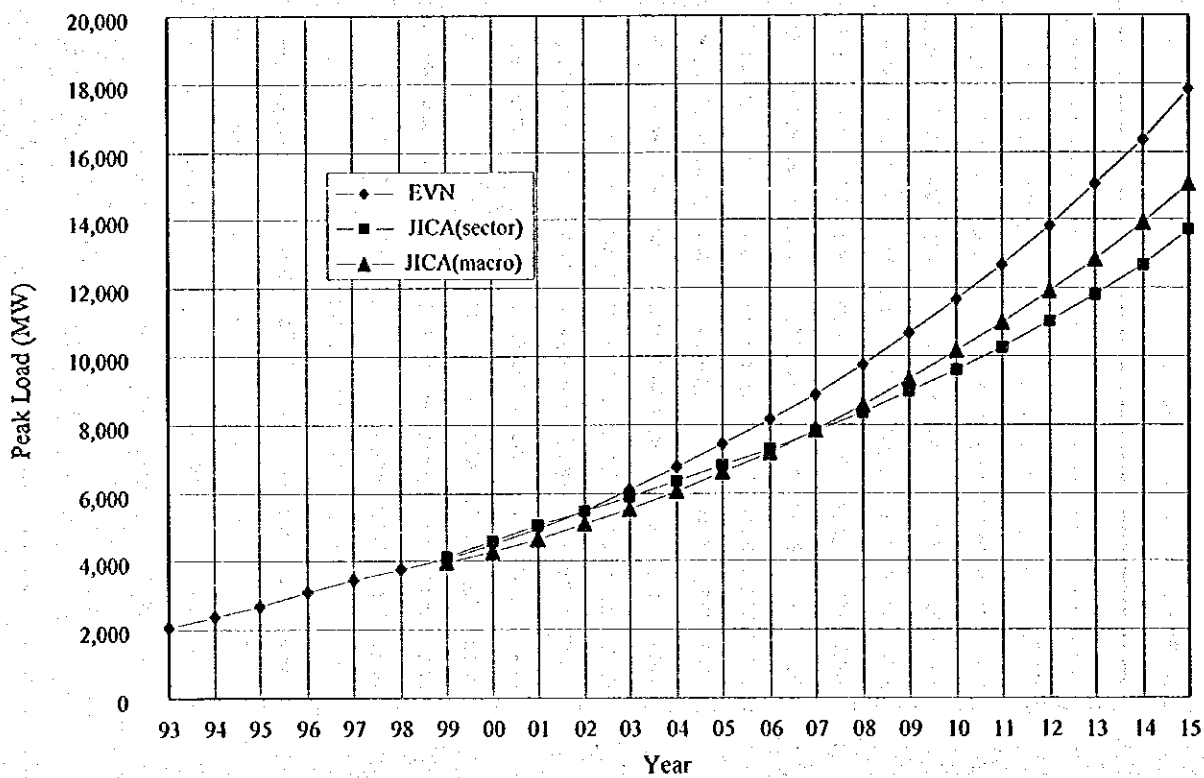

Figure 5.15 Peak Load Forecast by the JICA Study Team

CHAPTER 6 PROJECT FORMULATION

6.1 General Description on Procedures Applied to Optimization Study

6.1.1 General

Initially, the Dong Nai No.3 and No.4 schemes were identified on the Dong Nai mainstream through the past master plan study carried out by JICA. As described in Chapter 3, the Dong Nai No.4 scheme cannot have a sufficient reservoir capacity to allow the seasonal regulation of the streamflow due to the topographical condition that narrow gorges that continue over the river section from the Dong Nai No.3 dam site to the Dong Nai No.4 dam site. While, a comparatively wide valley spreads upstream of the Dong Nai No.3 dam site, making it possible to secure a sufficient reservoir capacity for the seasonal regulation.

Actually, the effective storage capacity of the Dong Nai No.4 reservoir is about 37 million m^3, which is equivalent to only about 1.2 % of the annual average inflow volume, even in case about 90 m high dam is constructed at the proposed location. In other word, the Dong Nai No.4 scheme would have to be developed as a run-of-river type, when it is operated independently without the upstream Dong Nai No.3 scheme. It is not economically attractive taking into account the long-lasting dry period in the Project area. Thus, the JICA master plan study on the Dong Nai river basin that was carried out in 1996 recommended the Dong Nai No.3 and No.4 schemes to be developed as a combined project.

The combined development of the Dong Nai No.3 scheme and Dong Nai No.4 scheme will enable the Dong Nai 4 scheme to receive the seasonally stable discharge regulated by the upstream Dong Nai No.3 reservoir. In this Feasibility Study, the Dong Nai No.4 reservoir is contemplated to regulate daily regulation of streamflow flowing from the intervening catchment area between the Dong Nai No.3 and No.4 dam sites.

Taking into account the operation mode of the Dong Nai No.4 power station that has to be subordinate to the operation of the Dong Nai No.3 reservoir, it is determined that the Dong Nai No.3 and No.4 Combined HPP is optimized as a combined scheme.

6.1.2 Likely Benefits Accrued from the Dong Nai No.3 and No.4 Combined HPP

The Dong Nai River with a catchment area about 30,000 km^2 is one of the major and principal river basins in Vietnam, being blessed with abundant water resource potentials attributed to annual rainfall of 2,000 to 3,000 mm. At present, there exists two storage type dams on the Dong Nai mainstream, namely Dran dam in the upper reach and Tri An dam in the middle reach. In addition, the Da Nhim and Da Queyon dams are going to be constructed on the Dong Nai mainstream and its tributary, respectively, under the on-going Dai Ninh HHP.

Since the Dai Ninh HPP is planned to divert streamflow of the Dong Nai mainstream to the eastern basin, the downstream reach will necessarily loose runoff yielded from a catchment area of 1,158 km^2 covered by the Dai Ninh HPP after it is completed. This will reduce power output of the existing Tri An power station as well as reduce the water supply capacity to the downstream municipalities including Ho Chi Minh City.

In addition to the power generation, the Dong Nai No.3 and No.4 Combined HPP will make up for the dry flow which is to be lost by the realization of the Dai Ninh HPP. From the long-term point of view, the Project will contribute to meet the increasing irrigation and municipal water demands in the downstream areas. Accordingly, the Dong Nai No.3 and No.4 HPP is expected to bring about the following tangible and intangible benefits:

a) Power generation by power plants of the Dong Nai No.3 and No.4 Combined HPP ,
b) Augmentation of power output of existing Tri An power station resulting from the regulation of streamflow by the Dong Nai No.3 reservoir,
c) Augmentation of water supply capacity to downstream areas for the purpose of irrigation and municipal water supply
d) Improvement of environment condition in downstream reach due to the increase of dry season's flow, after it will become draughty to some extent after the completion of Dai Ninh HPP

In reality, the water demand in downstream areas including Ho Chi Minh City is projected to increase at a higher growth rate in the near future. Therefore, it is obvious that the Dong Nai No.3 and No.4 Combined HPP will contribute not only to the power demand, but also to those in other water resources sectors such as irrigation and municipal water supply. In this Feasibility Study, on the other hand, only the benefits of items a) and b) above are incorporated in making the optimization study in this Chapter 6 as well as the project evaluation in the succeeding Chapter 9.

6.1.3 Procedures Applied to Optimization Study

The optimization study for determining the optimum development plan of the Dong Nai No.3 and No.4 Combined Hydropower Project was carried out in the following four steps:

(a) Step 1 : Selection of optimum project layout plan : This comparative study on various alternative project layout plans which were proposed in the previous studies and this Feasibility Study was carried out in the First Field Investigation lasting between the middle January and the middle of March 1999. In the comparative study, the topographic and geologic data obtained in the past pre-feasibility study that was performed by EVN in 1988 were utilized.

(b) Step 2 : Selection of the most favorable type and layout plan of such major structures as the Dong Nai No.3 and No.4 dams among from the development alternatives for the selected project layout plan in Step 1 above.

(c) Step 3: Determination of optimal development scale for the selected plans of main structures: The optimum development scale of the Project in terms of a full supply level of the Dong Nai No.3 reservoir was determined through the optimization study carried out based on the detailed field investigations including topographic survey and geologic investigation and construction materials survey in the Second and Third Field Investigations, that were performed for the optimum project layout plan selected in Step 1 above,

(d) Step 4 : Determination of the optimum daily peak operation hours and installation timing of the Dong Nai No.3 and No.4 power plants, taking into account the whole power system of Vietnam

The optimization study carried out through these steps is described in the following Sections.

6.2 Selection of Optimum Project Layout Plan, Performed in First Field Investigation

6.2.1 General

The comparative study of the alternative project layout plans was performed through the Preliminary Optimization Study in the First Field Investigation spanning the middle of January to the middle of March 1999. The study procedures, methods, and results are described in detail in the Progress Report No.1 submitted to EVN in March 1999 and Appendix E : Examination of Optimum Project layout Plan (Carried out in the First Field Investigation between January and March 1999) of Supporting Report of this Final Report. This Section 6.2 briefs the results of the comparative study for selecting the optimum project layout plan.

It has to be noted that, in principle, the Preliminary Optimization Study carried out in the First Field Investigation didn't aim at determining the optimum development scale of the Dong Nai No.3 and No.4 Combined Hydropower Project, but at selecting the optimum project layout plan thereof for which the detailed field investigation works were to be performed in the subsequent Second and Third Field Investigations.

6.2.2 Alternative Project Layout Plans Set up

To select the promising alternative project layout plans of the Dong No.3 and No.4 Combined HPP, the project layout plans proposed in the previous studies were carefully reviewed in the First Field Investigation based on the available topographic and geological data and information as well as the field reconnaissance. Especially, a focus was placed on a review of the project layout plans proposed in EVN's pre-feasibility study and JICA's master plan study. In addition to the project layout plans proposed in those previous studies, the reviewal study identified new locations for such main structures as the Dong Nai No.4 dam and waterway and powerhouse of the Dong Nai No.3. Consequently, five alternative project layout plans were worked out by combining the alternative sites for the following main structures:

a) Dong Nai No.3 dam site : Upstream dam site and downstream dam site that were proposed in the EVN's pre-feasibility study and JICA's master plan study

b) Waterway of Dong Nai No.3 : In addition to the waterway routes proposed in the previous studies, a new water way route aligned on the right bank was identified in the study stage.

c) Dong Nai No.4 dam site : two alternatives, namely upstream and downstream sites.

Concerning the downstream site for the Dong Nai No.4 dam site, two different sites were identified in the previous JICA's master plans study and EVN's pre-feasibility study. In the Preliminary Optimization Study carried out in the first Field Investigation, a new dam site was identified as the promising one. Of the three alternative for the downstream Dong Nai No.4 dam site, the new location approximately 700 m downstream of the dam site proposed in the previous ENV's pre-feasibility study was judged to be superior to the other two locations selected in the past studies through the cost comparison and field reconnaissance performed in the Preliminary Optimization Study. While, the upstream

No.4 dam site was identified at a location about 5 km upstream of the said downstream site. These two alternative sites for the Dong Nai No.4 dam which were retained to work out the alternative project layout plans are shown in Figure 6.1.

In addition to these alternative locations of main project components, the two alternatives with i) the lower height of Dong Nai No.4 dam and ii) the run-of-river development of Dong Nai No.4 scheme were contemplated. Consequently, the five alternative project layout plans were set up as the conceivable alternatives in the First Field Investigation as shown in Table 6.1 and Figure 6.1.

6.2.3 Economic Comparison of 5 Alternative Project Layout Plans

In making the comparison of the alternative project layout plans, as the first step, Alternative 1 and Alternative 2 proposed in the previous JICA master plan and pre-feasibility study, respectively, were examined to determine the favorable dam site of Dong Nai No.3 out of the two alternative dam sites, namely upstream and downstream dam sites, as well as the optimum development scale of the Dong Nai No.3 at a preliminary study level. The economic comparison of Alternative 1 and Alternative 2 was made applying the following two indices to measure their economic viability, namely i) Cost per kWh, and ii) Annual economic net benefit (B-C). It was verified through the comparative study that the Alternative 2 is much more economically viable than the Alternative 1. The following table summarizes the results of economic comparison of these two alternative project layout plans carried out in the Preliminary Optimization Study, setting a FSL of the Dong Nai No.3 at El.590m:

Economic Indices of Dong Nai No.3 and No.4 CHPP	Alternative 1 (Case 1-b)	Alternative 2 (Case 2-b)
	(FSL of Dong Nai No.3 dam : El.590 m)	
(26. Economic Cost per kWh (US Cent per kWh)	6.95	6.39
(26. Annual Economic Net Benefit (M. US$/year)	22.30	26.16

In succession, an economic comparison was made for four project layout plans of Alternative 2 to Alternative 5 setting a full supply level of the Dong Nai No.3 reservoir at El. 590 m. The following table summarizes the results of the economic comparison of the Alternative 2 to Alternative 4, which was carried out in the Preliminary Optimization Study:

Economic Indices of Dong Nai No.3 and No.4 CHPP	Alternative 2	Alternative 3	Alternative 4	Alternative 5
	(FSL of Dong Nai No.3 dam : El.590 m)			
- Annual Economic Net Benefit (M. US$/year)	26.16	22.33	21.27	17.48

It was found through this examination that the Alternative 2 would be the most economically viable in terms of annual net benefit. In addition, for each of the above alternative project layout plans, two different operation modes for the Dong Nai No.4 power station were examined. One is the operation mode with a minimum plant factor of 0.33 that is similar to that of the Dong Nai No.3 power station (OPM-1), the other is constant peak operation during a day with a plant factor of 1.0 that was categorized to be the so-called afterbay type or re-regulation type (OPM-2). As a result, Dong Nai No.4 was recommended to be developed as a peak-power station rather than a base-load power station from the economic point of view. The results of the comparison study carried out in the Preliminary Optimization study in the First field Investigation Study are discussed in detail in Appendix E of Supporting Report of this Final Report.

In accordance with the results of the comparison study of alternative project layout plans that were derived in the First Field Investigation, the detailed field investigation works including topographic survey, geological investigation, etc., were performed for the Alternative 2 of the Dong Nai No.3 & No.4 Combined HPP in the subsequent Second and Third Field Investigations.

6.3 Development Alternatives for Optimization Study

6.3.1 General

In the course of the First Field Investigation performed for the period of January 17 to March 20, 1999, the JICA Study Team worked out the optimum development scale of Dong Nai No.3 and No.4 Combined HPP at a preliminary study level with all data and information made available by the Study Team at that time. The development scale of the Project selected at the initial study stage was going to be finalized in the subsequent study through the incorporation of the results of the detailed field investigation.

The major points that may affect the selection of the optimum development plan from the engineering viewpoint were conceived as follows:

a) Type of the main dams
b) Layout of major components involved in the Dong Nai No.3 and No.4 schemes

Prior to the optimization study to determine the optimum development scale of the Project that is discussed in the following Section 6.4, the comparison study of dam types including layout of its appurtenant structures for the Dong Nai No.3 and No.4 schemes were made through incorporation of the results of the detailed field investigation.

In principle, the dam types of the Dong Nai No.3 and No.4 main dams were compared from technical aspects as well as straightforward cost aspects.

In addition to these two elements, a time element to complete the Project was taken into account in finally selecting the dam type, especially in the dam type of the Dong Nai No.3, considering that the optimum commissioning years of the Dong Nai No.3 and No.4 power plants are 2007 and 2008, respectively, through the power system analysis as described in the succeeding Section 6.5.

After finalization of the dam types and layout of its appurtenant structures for both of Dong Nai No.3 and No.4 schemes, the alternatives set up by varying a FSL of the Dong Nai No.3 dam were compared from the economic viewpoint in order to determine the optimum development plan of the Project as discussed in the succeeding Section 6.4.

6.3.2 Type of the Main Dams

Using 1:1,000 scale topographic maps and geo-technical data and information obtained through the detailed field investigation, the following types of dam were compared to find the most proper type of dams for No.3 and No.4 sites from technical and economic viewpoints:

a) Earth core rockfill dam (ECRD) type
b) Concrete face rockfill dam (CFRD) type
c) Conventional concrete gravity dam type
d) Combined type of concrete gravity dam and rockfill dam for the Dong Nai No.3 site

In addition to these four alternative types, a possibility of adopting the RCC dam type was considered, but it was discarded in this Feasibility Study since the stable supply of pozzolans (ground-granulated blast-furnace slag, high-lime fly-ash and limestone powder) was not able to be ensured from the local markets.

The dams and their major appurtenant structures designed for the alternative dam types of a) to d) above are illustrated in Figures 7.1, 7.2, 7.11 and 7.12 in the succeeding Chapter 7 and Figures 6.2 to Figure 6.6, respectively

From the technical viewpoint, it was judged that all of these dam types can be applied for the Dong Nai No.3 and No.4 schemes without any remarkable increase of construction costs. Therefore, it was determined that the optimal dam type for each of the Dong Nai No.3 and No.4 schemes be selected through the comparison of the construction costs taking into account the construction period which may have a significant influence of the commissioning timing of these schemes.

The economical comparison was made as shown in Tables 6.2 and 6.3 on the condition of FSL of the Dong Nai No.3 dam being at El.590m, since it is very likely to be selected as the optimum FSL from the optimization study done so far and the slight modification of the FSL from El.590m would not lead to modification of the results of the dam type selection.

As can be seen in Tables 6.2, conventional earth core rockfill dam (ECRD) and concrete face rockfill dam (CFRD) at No.3 dam site are more economical than other type of dams and the cost difference between conventional rock-fill dam and concrete face rock-fill dam is estimated to be approximately 10 million US$ in favor to conventional ECRD. However the concrete face rockfill dam has an advantage of shortening the construction period against the rockfill dam by about one year as described in Chapter 8. These two dam types for Dong Nia No.3 is compared from the economic and financial aspects as described below:

a) As described in Section 6.5, the best commissioning year of Dong Nai No.3 Project which can save the capital and O&M costs of whole power system of Vietnam most effectively is selected to be the year 2007 through the economic analysis using the software EGEAS. This conclusion is still valid, even though the project cost of Dong Nai No.3 would increase or decrease by 10 to 15 million US$. This shows that the CFRD which can be commissioned in 2007 is more economically advantageous than ECRD for Dong Nai No.3 Project from the economic viewpoint.

b) To compare the advantages of the CFRD and ECRD for Dong Nai No.3 from the financial aspect, FIRR of Dong Nai No.3 Project was estimated for each of these two cases applying the same criteria as those described in the succeeding Section 9.3. The total project cost and its annual disbursement schedule in the two cases are summarized below:

Total Capital Cost and its Annal Disbursement Schedule in Case of
CFRD and ECRD for Dong Nai No.3 Dam

(Unit : million US$)

No. of Year	1	2	3	4	5	6	7	8	Total Project Cost of Dong Nai No.3
- CFRD	4.3	11.0	25.8	52.5	88.6	122.5	91.7	-	396.4
- ECRD	3.7	10.2	23.7	39.6	83.6	90.8	78.9	51.8	382.3

For the both cases, the financial revenue after the commissioning of Dong Nai No.3 power station is 36.7 million US$, assuming the power tariff of 4.5 USc/kWh at the switchyard. Consequently, FIRRs of the Dong Nai No.3 Project is derived to be about 6.0% and 5.9% in case of CFRD and ECRD for the Dong Nai No.3 dam, respectively. For Dong Nai No.3 dam, accordingly, the CFRD is slightly more advantageous than ECRD, although there is no large difference the two FIRR values.

In conclusion, the concrete face rockfill dam type is recommended for Dong Nai No.3 dam.

Concerning Dong Nai No.4 dam, as can be seen in Tables 6.3, both conventional earth core rockfill dam (ECRD) and concrete face rockfill dam (CFRD) are also more economical than other type of dams and their cost differences will amount to approximately 10 million US$ between ECRD and CFRD in favor to ECRD.

There is also a possibility that adopting concrete face rockfill dam shortens the construction period of the Dong Nai No.4 scheme as well as the case of Dong Nai No.3 dam type. In case of the Dong Nai No.4, however, the critical path work is construction of the waterway rather than the dam construction, since it is unavoidable to lay out the waterway through widely spread hill where it is too hard to provide the work adits to shorten the construction period of the waterway.

Therefore, the earth core rockfill dam type is recommended for the dam type of Dong Nai No.4 as the least cost alternative dam type.

In reality, no CFRD type dams have been provided in Vietnam up to now. However, the CFRD is now an established type of rockfill dam in technology. In many feasibility studies, it is selected over other types of dams including earth core rockfill dam (ECRD) because of shorter construction period and/or lower cost. Further, many CFRD type dams have been successfully completed as can be seen in Table 7.1, which shows a part of the actual examples in the world. Therefore, it is highly recommended to adopt the CFRD for Dong Nai No.3 dam in order to develop the dam design and construction technologies in Vietnam from now on.

6.3.3 Project Layouts for No.3 and No.4 Project Components

The layout plans of main components involved in the Dong Nai No.3 and No.4 Combined HPP were reviewed on the basis of topographic maps at a scale of 1:1,000 and 1:10,000, and geo-technical data and information obtained through the detailed field investigation. As a result, the layout plans of the Dong Nai No.3 and No.4 schemes which comprise the following major features were worked out:

a) Dam axis
b) Location of diversion tunnels
c) Location of spillway
d) Location of power intake, headrace and power station

The layouts at No.3 and No.4 project sites thus worked out are illustrated in Figures 7.1, 7.2, 7.3, 7.6, 7.7, 7.9, and 7.10 for the Dong Nai No.3 scheme and Figures 7.11, 7.12, 7.13, 7.14, and 7.17 for the Dong Nai No.4 scheme, respectively.

Such adjustment as minor relocation of both No.3 and No.4 power stations would have to be carried out at the detailed design stage so as to further reduce excavation volumes required for construction of the powerhouses by expanding the areas of topographic survey at a scale of 1:1,000 and performing the minimum amount of core boring.

6.4 Optimization Study to Determine Development Scale of the Dong Nai No.3 and No.4 Combined HPP

6.4.1 Examined Development Cases

As discussed in Section 6.2, the most favorable layout plan for the Dong Nai No.3 and No.4 Combined HPP was determined to be Alternative 2. In the subsequent Second and Third Field Investigation, the detailed field investigations including topographic survey and geological investigation have been performed for Alternative 2. The outcomes of those field investigations are utilized to find the optimum development scale out of various alternatives envisaged for a project layout plan of Alternative 2.

The optimum plan for a hydroelectric project is the plan which yields the largest net benefit, defined as the net benefit minus the cost, both expressed in present worth. The optimization study aims principally at finding the optimum full supply level of the Dong Nai No.3 reservoir.

As described in foregoing Section 6.1, the Dong Nai No.4 power station needs to be operated using stable discharges regulated seasonally by the upstream Dong Nai No.3 reservoir as well as the discharges of intervening catchment area between the Dong Nai No.3 and No.4 dam sites that will be regulated by the Dong Nai No.4 reservoir. Since the regulated discharge from the Dong Nai No.3 accounts for a large part of available discharge for the Dong Nai No.4 power station, a full supply level of the Dong Nai No.4 reservoir is set at a tail water level of the Dong Nai No.3 power station. Taking into account the characteristic of power operation mode of the Dong Nai No.4 scheme subordinate to that of the Dong Nai No.3 scheme, the alternative development cases of Alternative 2 are set by varying the full supply level of the Dong Nai No.3 reservoir as follows:

Alternative Development Cases

Case No.	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7	Case-8
FSL of Dong Nai No.3 Reservoir (El. m)	575	580	585	590	595	600	605	610

6.4.2 Reservoir Operation Study and Power Output Calculation of the Dong Nai No.3 and No.4 Combined HPP

(1) Method and criteria

The reservoir operation study aims at defining the project outputs that are to be applied to the optimization study. It is noted that a reservoir operation study carried out at the feasibility study level doesn't extend to set up the comprehensive operation rule of the proposed Dong Nai No.3 and No.4 Combined HPP. Accordingly, the reservoir operation study was carried out applying the simplified operation rule as explained below.

Concerning the development cases, a reservoir operation study was carried out for each of the Dong Nai No.3 and No.4 reservoirs utilizing the following formula:

$$P = \xi \cdot g \cdot Qpi \cdot (H - H_{loss})$$

$$Vi = Vi\text{-}1 + (Qi - Qpi \cdot 24 \cdot PFi) \cdot Ni \cdot 0.0864 - Ai \cdot E \cdot Ni/1000$$

Where,

P	:	Peak power (kW)
G	:	Acceleration of gravity (=9.8 m/sec^2)
H	:	Gross head (m)
H_{loss}	:	Loss head in waterway (m)
ξ	:	Combined efficiency of turbine and generator (=0.89)
V_i	:	Remaining storage volume of i-th month (MCM)
V_{i-1}	:	Remaining storage volume of the previous month (MCM)
Q_i	:	Inflow discharge of i-th month (m^3/sec)
A_i	:	Reservoir area (km^2)
E	:	Evaporation (mm/day)
N_i	:	Number of days of i-th month
QP_i	:	Average power discharge of i-th month (m^3/sec)
PF_i	:	Daily plant factor

For all of the development cases, the rated reservoir water level is preliminarily set at an elevation of full supply level (FSL) minus one third a drawdown. The maximum power discharge is taken to generate the installed capacity at the rated reservoir water level. When the reservoir water level is above the rated water level, the power discharge required to generate the installed capacity becomes smaller than the maximum power discharge due to higher effective water head. When the reservoir water level is below it, the usable power discharge becomes smaller than the maximum power discharge so that generated power becomes smaller than the installed capacity.

The minimum daily plant factor is determined to be 0.313 based on the results of a optimization study on minimum daily peak operation hours of the Dong Nai No.3 and No.4 CHPP mentioned in Subsection 6.4.7 and in consideration of the likely portion to be shared by the Project in the typical daily load duration curve around year 2007 and with reference to the value adopted in the EVN's pre-feasibility study. The maximum power discharge is determined to keep the minimum plant factor of 0.313 throughout the whole hydrologic period by utilizing the effective storage volume. The firm energy is defined to be energy producible with the minimum plant factor, while the secondary energy to be energy generated in excess of the power generation with the minimum plant factor on the condition of the reservoir water level being at FSL. The dependable peak power is taken to be a power output that can be guaranteed over 90% of the entire hydrologic period.

(2) Basic Data

(a) Inflow data

The monthly runoff data at the Dong Nai No.3 dam site which are tabulated in Table 3.4 were used as the inflow series to the Dong Nai No.3 reservoir for every alternative development case. For each alternative development, the Dong Nai No.4 reservoir inflow data were derived by adding discharges released from the power station and spillway of the upstream Dong Nai No.3 to runoff from the intervening catchment area between the Dong Nai No.3 and No.4 dam sites. The mean monthly discharges shown in Table 3.5 are used as the runoff from the intervening catchment.

(b) Evaporation loss

The evaporation loss usually varies with the weather conditions such as air temperature, sunshine duration, wind velocity, etc. The monthly values shown in Table 3.2, which are estimated from the evaporation records in the Dong Nai River basin are applied to the reservoir operation study for the Dong Nai No.3 and No.4 reservoirs.

(c) Reservoir sedimentation and minimum operation level (MOL)

The denudation rate of the Project catchment is estimated at about 0.2 mm/year as discussed in Chapter 3. Adopting the reservoir life at 100 years and the trap efficiencies, the total sediment volumes deposited in the Dong Nai No.3 and No.4 reservoirs for the reservoir life are estimated at 84.6 and 5.1 million m3, respectively. Based on the sediment deposit volumes, the reservoir sediment levels are determined to store the total volumes for the Dong Nai no.3 and No.4 reservoirs, respectively. The sill level of the power intake structures are set at elevations higher than the reservoir sediment level. On the other hand, it is not necessarily economical to set the minimum operation level at the lower elevation from a viewpoint of the power generation. For the Dong Nai No.3 reservoir, the reservoir operation study revealed that a 30 m drawdown generally results in a economically favorable case. Likewise, a drawdown of 10 m is taken for the Dong Nai No.4 reservoir in order to keep its effective regulation function for runoff from a residual catchemnt intervening between the Dong Nai No.3 and No.4 dam sites. For each development case, the minimum operation levels of the Dong Nai No.3 and No.4 reservoirs are set securing more than two times the headrace tunnel diameter above the intake sill level.

(d) Tail water level of Dong Nai No.3 Power Station and full supply level of Dong Nai No.4 reservoir

Figure 6.7 shows discharge rating curves at the tailrace ends of the Dong Nai No.3 and No.4 power station sites, which were worked out through the uniform flow calculation. The plant discharges of the eight alternative development cases are in a range of 150 m3/sec to 300 m3/sec. In case that the Dong Nai No.3 scheme is independently constructed without the downstream Dong Nai No.4 scheme, the tail water level of the Dong Nai No.3 power station varies in a very small range of El. 439.5 m and El.439.7 m for its plant discharges of 150 m3/sec to 300 m3/sec. The Dong Nai 4 power station will be operated largely relying on the plant discharge released from the Dong Nai No.3 power station. The full supply level of the Dong Nai No.4 reservoir is set at El. 440 m and the tail water level of the Dong Nai No.4 power station was determined based on the discharge rating curve at the site.

(e) Reservoir storage curve

While the reservoir storage curve for Dong Nai No.3 was constructed in the pre-feasibility study based on 1:10,000 scale topographic maps, that for Dong Nai No.4 was worked out by the JICA Study Team based on the new 1:10,000 scale maps, prepared by EVN in September 1999. These storage curves shown in Figure 3.18 were applied to the reservoir operation study.

(3) Estimated Project Outputs

The dependable peak power and annual firm and secondary energies for the respective alternative development cases, which are calculated through this reservoir operation study, are listed in Table 6.4.

6.4.3 Incremental Power Output of Existing Tri An HPP

The existing Tri An dam located about 220 km downstream of the Dong Nai No.4 dam occupies a large catchment area of 14,025 km^2. The Tri An power station has been in operation since 1988. The main features of Tri An HPP are tabulated below:

Main Features of Existing Tri An HPP

Hydrology		Tri An Power Station	
· Catchment area	14,025 (km^2)	· Maximum plant discharge	880 (m^3/sec)
· Mean inflow	526 (m^3/sec)		
Tri An Reservoir		· Effective head	52 (m)
· Full supply level	62 (m)	· Installed capacity	400 (MW)
· Minimum operation level	50 (m)		
· Effective storage capacity	2,546 (m)		

During the field investigation, the inflow data to the Tri An reservoir between 1975 and 1995 were collected from EVN. The inflow data show that the Tri An reservoir has only 15% of average annual inflow volume. Accordingly, it was envisaged that a considerable amount of inflow discharges to the reservoir are spilled out through its spillway without utilizing them for power generation in the wet season. Furthermore, the dependable discharge will notably decrease after the completion of the upstream Dai Ninh HPP, since most of the dry season flow at the Dai Ninh HPP site is to be diverted to the eastern basin.

On the contrary, the streamflow to be regulated by reservoirs of the Dong Nai No.3 and No.4 Combined HPP as well as the Ham Thuan-Da Mi HPP being under construction will expand the project outputs consisting of dependable peak and annual energy outputs. Since the Dong Nai No.3 and No.4 Combined HPP is going to be commissioned after the completion of Ham Thuan-Da Mi HPP and Dai Ninh HPP, the reservoir operation study on the Tri An HPP was carried out on the following three conditions in order to estimate the incremental power outputs of existing Tri An HPP which will be attained through the realization of the Dong Nai No.3 and No.4 Combined HPP:

a) Condition 1 with Ham Thuan-Da Mi HPP
b) Condition 2 with Ham Thuan-Da Mi HPP and Dai Ninh HHPP (after completion of Dai Ninh HPP)
c) Condition 3 with Ham Thuan-Da Mi HPP, Dai Ninh HHPP and Dong Nai No.3 and No.4 Combined HPP (after completion of Dong Nai No.3 and No.4 Combined HPP)

A flow of the reservoir operation study to estimate the incremental power outputs of the Tri An HPP is shown in Figure 6.8. The incremental power output of the Tri An HPP is derived to be a difference between the power outputs producible under Conditions b) and c) above. For each of these eight alternative development cases, the incremental dependable discharges as well as power outputs of existing Tri An HPP were estimated through the reservoir operation study on the Tri An reservoir on the above two conditions.

With regard to Ham Thuan-Da Mi HPP, project features of and monthly inflow data proposed in their detailed design reports were applied to the reservoir operation study.

The estimated incremental power outputs of the Tri An reservoir for each development case is shown in Table 6.4, which reveals that the alternative development cases will augment the annual energy output of the Tri An HPP by 61 to 94 GWh/year, respectively. Likewise, the water supply capacity from the Tri An reservoir is to be expanded as shown in Table 6.4, although the incremental benefits attributed to the water supply are not taken into account in this feasibility study. The detailed calculation results in the development case-4 with a full supply of El. 590 m for the Dong Nai No.3 reservoir is shown in Table 6.5.

6.4.4 Estimate of Economic Cost

For each alternative development case set up above, the preliminary design was made applying the procedures and criteria described in Chapter 7 in order to quantify the major work items of the construction. The costs of each alternative case were estimated dividing them into the local and foreign currency portions.

The economic costs are assumed to be 100% and 95% of the foreign and local currency portions of the total cost, respectively, taking into account the transfer payments included in the local currency portions. The economic project costs for the respective development cases thus estimated are presented in Table 6.6. The economic costs were disbursed in accordance with the annual disbursement schedule explained in the succeeding Chapter 8.

6.4.5 Estimate of Economic Benefit

In addition to the power outputs of the Dong Nai No.3 and No.4 power stations, the incremental power outputs of existing Tri An HPP are also counted as the power benefits of the Dong Nai No.3 and No.4 HPP.

There are two kinds of methods to measure the benefit of the project. One is the least-cost alternative method in which the benefit is represented by the costs of the least alternative thermal and the other one is to estimate the benefit using the long-run marginal cost (LRMC) in the power system.

In the present optimization study, the economic benefits measured by the LRMC method is adopted in determining the optimum development plan. The long term marginal cost of the interconnected system is estimated at 0.07246 US$/kWh as discussed in Chapter 9. Besides, the consistency of the optimization study results is checked by the least-cost alternative method.

As explained in Chapter 5, the power systems of the north, central and south areas are interconnected by existing 500 kV transmission line. For the time being, electric power in the interconnected power system is being supplied by generating facilities with a total installed capacity of 5,055 MW, of which hydropower plants account for 2,854 MW equivalent to about 57 % of the total installed capacity. The remaining thermal power plants are shared by gas turbine (14.1%), coal-fired (12.8%), diesel power plants (7.9%), oil-fired (3.9%), and IPP power plants (4.9%). To meet the increasing power demand in future, EVN is planning to introduce hydropower, gas turbine, coal-fired, and combined cycle power plants. Of those thermal power plants, it is contemplated that the peak load portion in the daily load duration curve will be borne by the combined cycle and gas turbine power plants, the base load being stacked by the coal-fired power plants. While, the intermediate portion will be borne by hydropower and combined cycle power plants. Especially after the year 2007, hydropower plants and thermal power plants consisting of coal-fired and combined cycle type power plants only are planned to be installed in the interconnected power system according to the latest power development plan of EVN.

The Dong Nai No.3 hydropower station is expected to share the intermediate portion in the daily road duration curve under the normal condition. On the other hand, its power plants are able to generate electricity over a longer time than 7.5 hours a day when excess water becomes available for power generation in the wet season. Thus, the Dong Nai No.3 power station will be operated as if it is a composite thermal of combined cycle and coal-fired thermal power plants. The Dong Nai No.4 power station may take the typical operation mode of the composite thermal, since one of the power units may be operated to keep the downstream maintenance flow so that it will bear both of the peak and base loads in the daily load duration curve. It is assessed through the examination that the least-cost alternative thermal plant is a composite thermal plant of combined cycle and coal-fired thermal power plants. The project benefit for each alternative development case in the least-cost alternative method was estimated based on the kW and kWh values of the combined cycle and coal-fired thermal power plants in proportion to their total installed capacities planned to be installed in the future as explained in the succeeding Chapter 9.

The estimated benefits of the eight alternative development cases in the LRMC and least-cost alternative method are shown in Table 6.6.

6.4.6 Selection of the Optimum Development Case

To estimate the net benefits of the alternative development cases, a cash flow stream of their annual economic costs and benefits for 50 years was prepared therefor. The economic net benefits of the eight alternative cases, which were derived applying the procedures and criteria mentioned above, are shown in Table 6.7 and Figure 6.9 and summarized below:

Economic Annual Net Benefit of Alternative Development Cases
in case of Economic Benefit being Measured by the LRMC

(Unit : Million US$)

Economic Values	Alternative Development Case (FSL of Dong Nai No.3 Reservoir in El. m)							
	Case-1 (575)	Case-2 (580)	Case-3 (585)	Case-4 (590)	Case-5 (595)	Case-6 (600)	Case-7 (605)	Case-8 (610)
Annual Economic Net Benefit	25.2	25.6	26.4	27.5	24.8	22.5	19.5	16.5

Note : A discount rate of 10 % is used to estimate the above annual economic values.

As seen in this table, Case-4 of a full supply level of the Dong Nai No.3 reservoir being El. 590 m is the most economically viable in terms of the annual economic benefit estimated by means of the LRMC method. Therefore, it was determined that further examination be performed for the Case-4 with regard to the feasibility-grade design, construction planning, economic evaluation, etc., as discussed in the succeeding Chapters.

Table 6.7 shows that, in case of the annual net benefits being estimated by means of the least-cost alternative method, Case-4 is the most viable development alternative, although the other three development alternatives of Case-5 to Case-7 with FSL of El.595m to El.605m are economically competitive to the Case-4.

6.4.7 Examination of Daily Minimum Peak Operation Hours

The total installed capacity of the Dong Nai No.3 and No.4 Combined HPP will increase with the decrease of the daily peak operation hour or daily minimum plant factor during the driest period. The optimum daily peak operation hour of hydropower plants is dependent largely on the portion in a daily load duration curve of the power system, which is to be born thereby after the commissioning year. Thus, the minimum daily plant factor needs to be optimized so that the total capital and operation cost of the whole power system of Vietnam is minimized taking into existing and candidate power plants therein. As discussed in Chapter 5, on the other hand, the peak power demand of the whole power system of Vietnam is projected to reach 7,821 MW in 2007 and 8,535 MW in 2008 MW, when the Dong Nai No.3 and No.4 power plants are scheduled to be commissioned, respectively. Since it is too complicate to configure a portion to be born by the Dong nai No.3 and No.4 CHPP in such a large-scale power system, the capital and operation cost of the whole power system of Vietnam were attempted to be estimated with the software package, EGEAS. Thus, the software package, "EGEAS (Electric Generation Expansion Analysis System)", developed by Massachusetts Institute of Technology (MIT) and Electric Power Research Institute (EPRI) in the United States, was applied to find out the optimum daily minimum operation hour, by which a present worth of the whole capital and operation cost of the power system of Vietnam is minimized. It has been often used to find the least-cost power development plan in such power systems, taking into account the capital and operation costs of not only the planned hydropower plant, but also the existing and candidate power plants as practiced in the following Section 6.5.

To determine the peak operation hour of the Dong Nai No.3 and No.4 power plants, the present worth of the whole capital and operation cost of the power system of Vietnam were estimated with the software package, EGEAS, for each of 5 alternative cases of 6-hours to 8-hours peak operation at half hour intervals.

In this examination, the same assumptions and conditions as those applied to determine the optimum power development plan with EGEAS in the following Section 6.5 are made to compute the present worth for each of the alternative cases.

Concerning the capital costs of those alternative cases, the waterway and power facilities costs increase with the reduction of the peak operation hour, while the dam cost is constant for every case. Adopting a 8-hour peak operation as the base case, the increase or decrease of the capital and operation cost of the whole power system of Vietnam in the respective alternative cases were compared as shown in Figure 6.9 and below:

Item	Alternative Cases on Peak Operation Hour				
	Case-A 6-hour	Case-B 6.5 hour	Case-C 7-hour	Case-D 7.5-hour	Case-E 8-hour
(1) Installed Capacity of the Dong Nai No.3 and No.4 CHPP (MW)	636	586	543	505	472
(2) Present-day Construction Cost of the Dong Nai No.3 and No.4 CHPP(US$ Million)	753.9	727.7	709.0	693.3	577.7
(3) Increase or Decrease in Present-day worth of Vietnamese Power System Cost to Case-E (Million US$)	58	46	34	-1	0

As seen above and in Figure 6.9, the case of 7.5-hour peak operation could save the whole power system cost to the maximum extent among the alternative cases, although there is not a significant difference between the costs of the two cases of 7.5-hour and 8-hour peak operation. In general, the hydropower project is planned to cope with 6 to 8 hours peak operation, rarely 4 to 5 hours peak operation, depending on the portion in the daily load duration curve which is born by the hydropower project in the future. Taking into account the uncertainty associated with the projection of the peak load increase in the future, it is recommended to formulate the Dong Nai No.3 and No.4 Combined HPP with 7.5-hour peak operation, which corresponds to a minimum daily plant factor of about 31%.

6.5 Examination of Optimum Commissioning Year for Dong Nai No. 3 and No. 4 Hydropower Stations

6.5.1 Long-term Power Source Development Plan

Based on the long-term power demand forecast conducted by the JICA Study Team, the long-term power source development plan covering the period up to 2015 was examined using the software package, "EGEAS". With the software, the computer automatically calculates the optimum power development plan to meet the power demands over the evaluation period based on the following criteria:

- A constant ratio of the reserve capacity to the total power demand in the power system is maintained throughout the evaluation period.
- The candidate power plants put into operation during the evaluation period as well as their commissioning years are determined to meet the power demand of the power system so that the present worth of all capital and O&M costs of the power system is minimized.

The software package was applied to find the optimum commissioning years of the Dong Nai No.3 and No.4 power plants, as well as the least cost sequence of the candidate power plants added to the whole power system of Vietnam. Further explanation of EGEAS is presented in Appendix F of Supporting Report of this Final Report.

6.5.2 Conditions and Assumptions

The studies to search for the optimum commissioning years of the Dong Nai No.3 and No.4 power plants were carried out on the following conditions and assumptions:

- The power demands of the whole Vietnamese power system until the year 2015 are met through the integrated operation of the candidate power plants, existing power plants, and the priority power plants whose commissioning has already been finalized. The candidate power plants are selected from among those listed in the IOE's power source development plan.
- Power outage rate or loss of load probability (LOLP) is given 10 days in a year.
- Installed power facility has to meet the growing demands of power (MW) and energy (GWh) which are estimated in the foregoing Subsection 5.5.4.
- Minimum reserve margin is assumed to be 25 %.
- Table 6.8 shows a list of existing and committed units of hydropower and thermal plants in Vietnam.
- Table 6.8 also shows a list of planned (generic) power plants. Six hydropower stations including the Dong Nai No.3 and No.4 Combined Hydropower Project are considered as planned plants. Steam coal fired power plants of 300 MW and 500 MW are nominated as planned thermal plants. Combined cycle power plants of 300 MW and 430 MW are also conceived as the planned ones.
- Installed capacity and annual average energy of Dong Nai No.3 and No.4 hydropower plant are shown in Table 6.8.
- Average project life of thermal and hydropower plant is fixed at 25 years and 50 years, respectively.
- The construction plan in Section 8.1 reveals that the constructions of the Dong Nai

No.3 and No.4 schemes are scheduled to be completed in 2007 and 2008, respectively. Therefore, the Dong Nai No.3 and No.4 hydropower plants can be committed to commence power generation in 2007 and 2008, respectively, that are regarded as their earliest possible timings. Accordingly, the Dong Nai No.3 and No.4 Combined HPP can become one of the promising candidate projects to meet the power demand after 2007.

- The year of 1998 was set as the base year, and the present worth of whole capital and O&M costs for the 17 years from 1999 to 2015 is estimated by running EGEAS.

The optimum power development plan, which would have the least total cost among a numerous number of conceivable development alternatives, was derived through applying EGEAS, which introduces the concept of the Dynamic Programming (DP).

6.5.3 Optimum Commissioning Year for Dong Nai No.3 and No.4 Hydropower Stations

The calculation results are indicated in Table 6.9 and Figure 6.10, and summarized below:

Year	North		Central		South	
1999					Ba Ria	120
					Tra Noc	75
2000			Yali	360	Wartsila	120
			Song Binh	70	Phu My	240
					Ham Thuan - Da Mi	475
2001	Pha Lai	300			Ba Ria	56
2002			Can Don	72	Soc Trang	475
2003	Na Duong	100			Phu My	240
	Cao Ngan	100				
2004					O Mon	300
					Dai Ninh	300
2005			Yali	360	Phu My	240
			Se San 3	260		
2006	Pha Lai	300			O Mon	300
2007	Dai Tri	300			Dong Nai No.3	240
	Coal-2	500				
2008	Coal-2	500			Dong Nai No.4	270
2009	Coal-2	1,000				
2010	Coal-2	1,000				
2011					CC-1	600
					CC-2	430
2012	Son La	600			CC-1	600
	Coal-1	300				
2013	Son La	600			CC-2	430
	Coal-1	300				
2014	Son La	600	Se San 4	330	CC-1	300
			Plei Krong	120		
2015	Son La	600			CC-2	860

EGEAS found out that the Dong Nai No.3 and No.4 hydropower plants are best installed in the year 2007 and 2008, which coincides with the earliest commissioning year of each power plant in the construction plan presented in the succeeding Section 8.1. Accordingly, the Dong Nai No.3 and No.4 power plants are recommended to be added to the power system in 2007 and 2008, respectively.

Table 6.1 Combination of Main Project Components for 5 Alternative Project Layout Plans

Alternative Project Layout Plan	Combination of Main Components of the Project			Characteristics of the Alternative Project Layout Plan
	(1) Location of Dong Nai No.3 dam site	(2) Alignment of Dong Nai No.3 Waterway Route	(3) Location of Dong Nai No.4 dam site	
1. Alternative 1	Upstream site	Left bank	Downstream site	The location of Dong Nai No.3 dam site is same as that proposed in the previous JICA Master Plan study.
2 Alternative 2	Downstream site	Right bank	Downstream site	This project layout plan is similar overall to that proposed in the EVN's pre-feasibility study with the exception of the Dong Nai No. 3 waterway route, which is aligned on the right bank as a result of the examinations made based on the topographic information obtained from EVN in the First Field Investigation.
3. Alternative 3	Downstream site	Left bank	Downstream site	The Dong Nai No.4 dam is planned to be much smaller than that of Alternative 1 and Alternative 2 by 38 m in order to reduce the No.4 dam cost, which accounts for a large portion of total project cost. The head which is lost by scale-down of the Dong Nai No.4 dam is recovered by extension of the Dong Nai No.3 headrace tunnel.
4. Alternative 4	Downstream site	Right bank	Upstream site	The upstream site of Dong Nai No.4 dam is adopted instead of the downstream dam site in Alternative 1 to Alternative 3. The Dong Nai No.4 headrace tunnel is extended in compliance with the change of the Dong Nai No.4 dam location.
5. Alternative 5	Downstream site	Right bank	Upstream site	The Dong Nai No.4 scheme is developed as a run-of-river type in which discharge from the Dong Nai No.3 power station is not regulated with the Dong Nai No.4 reservoir. A head tank is planned to be provided on the Dong Nai No.4 waterway.

Notes: 1 These alternative project layout plans were worked out and compared in the First Field Investigation stage. The results of the comparison study are described in detail in the progress Report No.1 submitted to EVN in March 1999.

2 The main features of the 5 alternative layout plans that were compared in the First Field Investigation are shown in Appendix E in Supprting Report II.

Table 6.2 Dam Type Cost Comparison for Dong Nai No.3

Cost Items	Unit	Rockfill Dam Quantity	Rockfill Dam Unit price (US$) FC	Rockfill Dam Unit price (US$) LC	Rockfill Dam Amount (1000 US$) FC	Rockfill Dam Amount (1000 US$) LC	Rockfill Dam Amount (1000 US$) Total	Concrete Gravity Dam Quantity	Concrete Gravity Dam Unit price (US$) FC	Concrete Gravity Dam Unit price (US$) LC	Concrete Gravity Dam Amount (1000 US$) FC	Concrete Gravity Dam Amount (1000 US$) LC	Concrete Gravity Dam Amount (1000 US$) Total
Civil Work					52,893	44,031	96,924				75,873	83,287	159,160
2) Temporary river diversion					10,734	10,083	20,817				9,184	8,175	17,359
Excavation, tunnel	m³	234,838	26.0	16.0	6,106	3,757	9,863	170,322	26.0	16.0	4,428	2,725	7,154
Tunnel supporting work	LS	25%			1,526	939	2,466	25%			1,107	681	1,788
Concrete, lining	m³	45,797	52.0	73.0	2,381	3,343	5,725	33,215	52.0	73.0	1,727	2,425	4,152
Re-bar	t	1,832	10.0	755.0	18	1,383	1,401	1,329	10.0	755.0	13	1,003	1,017
Main cofferdam	m³	0	3.4	2.1	0	0	0	380,000	3.4	2.1	1,307	806	2,113
Others (open works, etc.)		7%			702	660	1,362	7%			601	535	1,136
3) Dam					34,331	20,782	55,113				66,689	75,112	141,801
Excavation, common	m³	882,000	1.7	1.2	1,499	1,058	2,558	282,000	1.7	1.2	479	338	818
Excavation, rock	m³	226,000	4.8	2.7	1,085	610	1,695	111,000	4.8	2.7	533	300	833
Embankment, core	m³	1,036,000	2.6	1.7	2,694	1,761	4,455	0	2.6	1.7	0	0	0
Embankment, filter	m³	288,000	16.7	8.7	4,810	2,506	7,315	0	16.7	8.7	0	0	0
Embankment, rock	m³	5,049,000	3.8	2.3	19,186	11,613	30,799	0	3.8	2.3	0	0	0
Concrete, dam	m³	0	32.0	35.0	0.0	0.0	0.0	1,738,000	32.0	35.0	55,616.0	60,830.0	116,446.0
Concrete, structure	m³	0	30.0	63.0	0.0	0.0	0.0	87,490	30.0	63.0	2,624.7	5,511.9	8,136.6
Concrete, face slab	m³	0	54.0	71.0	0.0	0.0	0.0	0	54.0	71.0	0.0	0.0	0.0
Re-bar	t	0	10.0	675.0	0.0	0.0	0.0	1,750	10.0	675.0	17.5	1,181.3	1,198.8
Grout work													
Blanket grout	m	14,200	33.0	22.0	469	312	781	21,600	33.0	22.0	713	475	1,188
Curtain grout	m	41,100	57.0	38.0	2,343	1,562	3,905	41,100	57.0	38.0	2,343	1,562	3,905
Others		7%			2,246	1,360	3,606	7%			4,363	4,914	9,277
4) Spillway					7,828	13,167	20,995				0	0	0
Excavation, common	m³	1,108,700	1.7	1.2	1,885	1,330	3,215	0	1.7	1.2	0	0	0
Excavation, rock	m³	277,200	4.8	2.7	1,331	748	2,079	0	4.8	2.7	0	0	0
Concrete, structure	m³	127,130	30.0	63.0	3,814	8,009	11,823	0	30.0	63.0	0	0	0
Concrete, replaced	m³	10,440	25.0	48.0	261	501	762	0	25.0	48.0	0	0	0
Re-bar	t	2,543	10.0	675.0	25	1,716	1,742	0	10.0	675.0	0	0	0
Others		7%			512	861	1,373	7%			0	0	0

Cost Items	Unit	Combined Dam Quantity	Combined Dam Unit price (US$) FC	Combined Dam Unit price (US$) LC	Combined Dam Amount (1000 US$) FC	Combined Dam Amount (1000 US$) LC	Combined Dam Amount (1000 US$) Total	Concrete Face Rockfill Dam Quantity	Concrete Face Rockfill Dam Unit price (US$) FC	Concrete Face Rockfill Dam Unit price (US$) LC	Concrete Face Rockfill Dam Amount (1000 US$) FC	Concrete Face Rockfill Dam Amount (1000 US$) LC	Concrete Face Rockfill Dam Amount (1000 US$) Total
Civil Work					93,391	95,384	188,776				56,255	51,169	107,424
2) Temporary river diversion					12,133	10,945	23,078				12,310	11,111	23,421
Excavation, tunnel	m³	234,838	26.0	16.0	6,106	3,757	9,863	238,709	26.0	16.0	6,206	3,819	10,026
Tunnel supporting work	LS	25%			1,526	939	2,466	25%			1,552	955	2,506
Concrete, lining	m³	45,797	52.0	73.0	2,381	3,343	5,725	46,552	52.0	73.0	2,421	3,398	5,819
Re-bar	t	1,832	10.0	755.0	18	1,383	1,401	1,862	10.0	755.0	19	1,406	1,424
Main cofferdam	m³	380,000	3.4	2.1	1,307	806	2,113	380,000	3.4	2.1	1,307	806	2,113
Others (open works, etc.)		7%			794	716	1,510	7%			805	727	1,532
3) Dam					81,258	84,440	165,698				36,117	26,891	63,008
Excavation, common	m³	750,000	1.7	1.2	1,275	900	2,175	706,000	1.7	1.2	1,200	847	2,047
Excavation, rock	m³	187,000	4.8	2.7	898	505	1,403	181,000	4.8	2.7	869	489	1,358
Embankment, core	m³	625,000	2.6	1.7	1,625	1,063	2,688	0	2.6	1.7	0	0	0
Embankment, filter	m³	175,000	16.7	8.7	2,923	1,523	4,445	508,800	11.9	6.0	6,055	3,053	9,108
Embankment, rock	m³	3,030,000	3.8	2.3	11,514	6,969	18,483	4,659,200	3.8	2.3	17,705	10,716	28,421
Concrete, dam	m³	1,580,000	32.0	35.0	50,560.0	55,300.0	105,860.0	0	32.0	35.0	0.0	0.0	0.0
Concrete, structure	m³	140,000	30.0	63.0	4,200.0	8,820.0	13,020.0	2,500	30.0	63.0	75.0	157.5	232.5
Concrete, face slab	m³	0	54.0	71.0	0.0	0.0	0.0	50,900	54.0	71.0	2,748.6	3,613.9	6,362.5
Re-bar	t	2,800	10.0	675.0	28.0	1,890.0	1,918.0	4,270	10.0	675.0	42.7	2,882.3	2,925.0
Grout work													
Blanket grout	m	17,500	33.0	22.0	578	385	963	6,500	33.0	22.0	215	143	358
Curtain grout	m	41,100	57.0	38.0	2,343	1,562	3,905	85,000	57.0	38.0	4,845	3,230	8,075
Others		7%			5,316	5,524	10,840	7%			2,363	1,759	4,122
4) Spillway					0	0	0				7,828	13,167	20,995
Excavation, common	m³	0	1.7	1.2	0	0	0	1,108,700	1.7	1.2	1,885	1,330	3,215
Excavation, rock	m³	0	4.8	2.7	0	0	0	277,200	4.8	2.7	1,331	748	2,079
Concrete, structure	m³	0	30.0	63.0	0	0	0	127,130	30.0	63.0	3,814	8,009	11,823
Concrete, replaced	m³	0	25.0	48.0	0	0	0	10,440	25.0	48.0	261	501	762
Re-bar	t	0	10.0	675.0	0	0	0	2,543	10.0	675.0	25	1,717	1,742
Others		7%			0	0	0	7%			512	861	1,373

Note : Full Supply Level (FSL) of Dong Nai No.3 dam was set at El.590 m.

Table 6.3 Dam Type Cost Comparison for Dong Nai No. 4

Cost Items	Unit	Rockfill Dam						Concrete Gravity Dam						Concrete Face Rockfill Dam					
		Quantity	Unit price (US$)		Amount (1000 US$)			Quantity	Unit price (US$)		Amount (1000 US$)			Quantity	Unit price (US$)		Amount (1000 US$)		
			FC	LC	FC	LC	Total		FC	LC	FC	LC	Total		FC	LC	FC	LC	Total
Civil Work					32,811	36,457	69,268				37,220	43,876	81,096				37,323	42,258	79,581
2) Temporary river diversion					8,310	7,859	16,168				6,661	5,747	12,408				10,802	9,663	20,465
Excavation, tunnel	m^3	177,449	26.0	16.0	4,614	2,839	7,453	107,758	26.0	16.0	2,802	1,724	4,526	196,189	26.0	16.0	5,101	3,139	8,240
Tunnel supporting work	LS	25%			1,153	710	1,863	25%			700	431	1,131	25%			1,275	785	2,060
Concrete, lining	m^3	36,079	55.0	75.0	1,984	2,706	4,690	21,910	55.0	75.0	1,205	1,643	2,848	39,890	55.0	75.0	2,194	2,992	5,186
Re-bar	t	1,443	10.0	755.0	14	1,090	1,104	876	10.0	755.0	9	661	670	1,596	10.0	755.0	16	1,205	1,221
Main cofferdam	m^3	0	3.9	2.3	0	0	0	391,000	3.9	2.3	1,509	911	2,420	391,000	3.9	2.3	1,509	911	2,420
Others (open works, etc.)		7%			544	514	1,058	7%			436	376	812	7%			707	632	1,339
3) Dam					13,359	9,649	23,008				30,559	38,129	68,688				15,359	13,599	28,958
Excavation, common	m^3	258,000	1.8	1.3	464	335	800	91,000	1.8	1.3	164	118	282	206,000	1.8	1.3	371	268	639
Excavation, rock	m^3	37,000	5.2	2.9	192	107	300	37,000	5.2	2.9	192	107	300	29,000	5.2	2.9	151	84	235
Embankment, core	m^3	383,000	2.6	1.7	996	651	1,647	0	2.6	1.7	0	0	0	0	2.6	1.7	0	0	0
Embankment, filter	m^3	114,000	9.8	18.0	1,117	2,052	3,169	0	9.8	18.0	0	0	0	207,760	7.1	13.4	1,475	2,784	4,259
Embankment, rock	m^3	1,814,000	4.4	2.6	7,982	4,716	12,698	0	4.4	2.6	0	0	0	1,671,240	4.4	2.6	7,353	4,345	11,699
Dam concrete	m^3	0	34.0	37.0	0.0	0.0	0.0	652,000	34.0	37.0	22,168.0	24,124.0	46,292.0		34.0	37.0	0.0	0.0	0.0
Concrete, structure	m^3	0	32.0	64.0	0.0	0.0	0.0	129,600	32.0	64.0	4,147.2	8,294.4	12,441.6	1,700	32.0	64.0	54.4	108.8	163.2
Concrete, face slab	m^3	0	56.0	72.0	0.0	0.0	0.0	0	56.0	72.0	0.0	0.0	0.0	19,600	56.0	72.0	1,097.6	1,411.2	2,508.8
Re-bar	t	0	10.0	675.0	0.0	0.0	0.0	2,592	10.0	675.0	25.9	1,749.6	1,775.5	1,706	10.0	675.0	17.1	1,151.6	1,168.6
Grout work																			
Blanket grout	m	7,800	33.0	22.0	257	172	429	11,000	33.0	22.0	363	242	605	4,800	33.0	22.0	158	106	264
Curtain grout	m	25,900	57.0	38.0	1,476	984	2,461	26,300	57.0	38.0	1,499	999	2,499	64,500	57.0	38.0	3,677	2,451	6,128
Others		7%			874	631	1,505	7%			1,999	2,494	4,494	7%			1,005	890	1,894
4) Spillway					11,143	18,949	30,092				0	0	0				11,162	18,996	30,157
Excavation, common	m^3	1,295,040	1.8	1.3	2,331	1,684	4,015	0	1.8	1.3	0	0	0	1,295,040	1.8	1.3	2,331	1,684	4,015
Excavation, rock	m^3	323,760	5.2	2.9	1,684	939	2,622	0	5.2	2.9	0	0	0	323,760	5.2	2.9	1,684	939	2,622
Concrete, structure	m^3	181,150	32.0	64.0	5,797	11,594	17,390	0	32.0	64.0	0	0	0	181,710	32.0	64.0	5,815	11,629	17,444
Concrete, replaced	m^3	20,960	27.0	50.0	566	1,048	1,614	0	27.0	50.0	0	0	0	20,960	27.0	50.0	566	1,048	1,614
Re-bar	t	3,623	10.0	675.0	36	2,446	2,482	0	10.0	675.0	0	0	0	3,634	10.0	675.0	36	2,453	2,489
Others		7%			729	1,240	1,969	7%			0	0	0	7%			730	1,243	1,973

Note : Full Supply Level (FSL) of Dong Nai No.4 dam was set at EL.440 m.

Table 6.4 Summary of Project Output of Alternative Development Cases

Alternative Layout Plan		Alternative 2-b (selected in Progress Report No.1)							
Development Case		1	2	3	4	5	6	7	8
Dong Nai No.3	Dam Site Alternative	Downstream Site (Proposed in Pre-F/S)							
	Catchment Area (km^2)	2,441							
	FSL. (El. m)	575	580	585	590	595	600	605	610
	MOL. (EL. m)	545	550	555	560	565	570	575	580
	Effective Capacity (10^6m^3)	834	963	1,106	1,248	1,404	1,560	1,725	1,891
	TWL. (EL. m)	440							
	Firm Discharge (m^3/s)	59.5	61.9	64.6	66.6	68.4	70.0	71.1	71.9
	Max. Discharge (m^3/s)	190.4	198.1	206.7	213.1	218.9	224.0	227.5	230.1
	Installed Capacity (MW)	188	204	223	240	255	271	285	298
	90%Firm Peak Power (MW)	163	181	200	218	237	252	264	273
	Firm Energy (GWh/year)	494	540	591	636	682	724	762	794
	Secondary Energy (GWh/year)	156	138	117	100	84	66	52	41
	Total Energy (GWh/year)	650	678	708	736	766	790	814	835
Dong Nai No.4	Dam Site Alternative	Proposed Site in this study							
	Catchment Area (km^2)	159							
	FSL. (EL. m)	440							
	MOL. (EL. m)	430							
	Effective Capacity (10^6m^3)	37							
	TWL. (EL. m)	290							
	Firm Discharge (m^3/s)	62.8	65.2	67.9	69.9	71.7	73.3	74.4	75.2
	Max. Discharge (m^3/s)	201.0	208.6	217.3	223.7	229.4	234.6	238.1	240.6
	Installed Capacity (MW)	239	248	259	270	274	280	284	287
	90%Firm Peak Power (MW)	229	238	248	256	262	268	273	276
	Firm Energy (GWh/year)	645	671	700	721	740	758	770	779
	Secondary Energy (GWh/year)	191	166	140	120	102	85	73	64
	Total Energy (GWh/year)	836	837	840	841	842	843	843	843
Tri An	Increase of Firm Discharge (m^3/s)	42	44	46	48	50	52	53	54
	Increase of Firm Peak Power (MW)	2	2	2	2	2	2	2	2
	Increase of Firm Energy (GWh/year)	161	172	181	188	196	204	207	210
	Increase of Secondary Energy (GWh/year)	-100	-103	-106	-108	-110	-112	-114	-116
	Increase of Total Energy (GWh/year)	61	69	75	80	86	92	93	94

Notes

1. The rated water level (RWL) and Maximum discharge (Q_{peak}) for each case above were calculated based on the following formula:
   - RWL = FSL - (FSL - MOL) * 2/3
   - QP_{ex} = Firm Discharge * 24 / Peak duration hours (7.5 hours)
2. The increments of firm peak power, firm energy and secondary energy of the downstream existing Tri An power station were calculated based on following condition: Amount of Energy Increase at Tri An P.S. = (Energy at Tri An P.S. with Ham Thuan, Da Mi, Dai Ninh and Dong Nai3,4 P.S.) − (Energy at Tri An P.S. with Ham Thuan, Da Mi and Dai Ninh P.S.)